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RESTORATION OF THE BARRY PAINTINGS

[By courtesy of The Times

Detail from 'Elysium', showing the difference between a test patch which has been cleaned down to the paint and the rest of the canvas

The paintings by James Barry in the Lecture Hall, although regularly inspected, have undergone little more than surface cleansing in the last eighty years. During this time they have not only darkened with age: there has been an accumulation of the dirt which has not responded to superficial treatment, and some staining of the varnish. The paintings are now being submitted to a thorough and expert process of cleaning and restoration, in the course of which the discoloured varnish is being removed and replaced by a fresh varnish.

When this work is completed, at the end of September, the canvases will be in a state more nearly approaching their pristine condition, and more fit for critical scrutiny, than they have been for a considerable period.

A descriptive note on the Barry paintings, based on the artist's own explanation, is available at the Society's House for those Fellows and visitors who are not already familiar with the themes and persons represented in these six great pictures.

[By courtesy of The Times

The painting of 'The Society' after cleaning

THE SOCIETY'S CHRISTMAS CARD

It is expected to fulfil orders for the Society's Christmas card by the end of September. Fellows who intend to order are asked to do so as soon as they can. An order form, which includes a picture of the card and details of prices, is included at the back of this *Journal.*

INDUSTRIAL ART BURSARIES EXHIBITION

The exhibition of designs submitted in the 1958 Industrial Art Bursaries Exhibition will be on view at the Newcastle-upon-Tyne College of Art and Industrial Design from 28th September until 12th October. From 19th October until 2nd November the exhibition can be seen at the Stoke-on-Trent College of Art.

RESEARCH IN TEXTILES

Three Cantor Lectures

I. RESEARCH IN WOOL

by

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Monday, 20th April, 1959

The purpose of this lecture is to review recent advances in knowledge of the structure of the wool fibre and their bearing on the methods which are commonly used for assessing quality in wool. Skill in selecting the wools which are best suited for particular purposes provides the foundation for the prosperity of the wool textile industry of the United Kingdom, and a subconscious recognition of this fact is, no doubt, responsible for the reluctance of the industry to blend other fibres with wool. As, however, the newer man-made fibres have transformed the consumer's impressions of what is to be expected of a textile fabric as regards serviceability, any refusal to blend man-made fibres with wool cannot be justified unless the performance of all-wool fabrics can be modified at will to meet particular needs. The response of the wool textile industry to this challenge is discussed in the second part of the lecture.

THE COMPOSITION AND STRUCTURE OF THE WOOL FIBRE

Systematic scientific study of the materials and processes of the wool textile industry began about 40 years ago. At first, progress was slow because attempts to characterize wool keratin by elementary analysis were frustrated by baffling variations in composition. Chief attention was given to the sulphur content, which was found to vary, not only from wool to wool, but also along the length of a single staple. In addition, the cuticular and cortical cells were found to have a higher sulphur content than the intercellular phase, while the medullary cells, when present, were almost devoid of sulphur. It was only when attention was transferred from elementary to amino-acid analysis that it became possible to postulate a skeleton structure, which, besides being characteristic of all wools, was capable of accommodating the variations in composition. According to this simplified view, the fibre consists of long polypeptide chains, which are arranged roughly parallel to the length of the fibre and are linked together by cystine and salt linkages, the latter being derived from acidic (aspartic and glutamic acid) and basic (arginine and lysine) side-chains. The cross-linking was believed to be two-dimensional, and cohesion between the 'grids' was attributed to van der Waals forces and hydrogen bonds. X-ray examination and studies of the elastic properties of wool fibres showed that the polypeptide chains of unstretched

fibres are folded (α-keratin) and unfold when the fibres are stretched (β-keratin). For some 20 years after its conception, this structure provided a satisfactory basis for the study and interpretation of well-established processes in the wool textile industry, and faith in its essential validity was strengthened by the fact that inductive reasoning from the structure led to the development of a number of processes, including a range of new methods of making wool unshrinkable.

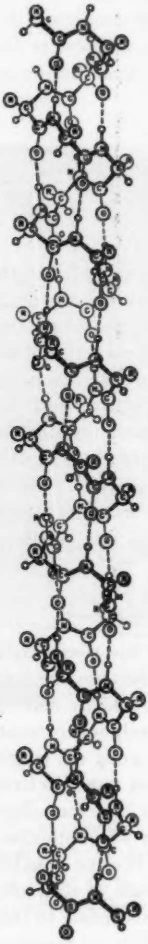

FIGURE 1. *Spiral configuration of the chain molecules of α-keratin. (Reproduced from* Nature, *by courtesy of Macmillan & Co., Ltd.)*

Simultaneously with its use, the skeleton structure of keratin has been amplified and characterized with steadily increasing precision. Following Sanger's procedure,[1] animal fibres of different types were treated with 1-fluoro-2:4-dinitrobenzene (FDNB) so as to label the amino-acids which provide the terminal amino groups of the polypeptide chains. Chromatographic separation of the substituted amino-acids from the hydrolysate of the treated fibres showed that with fibres as dissimilar as human hair and Lincoln, New Zealand Romney, and Australian merino wools the terminal amino groups are always provided by the same seven amino-acids, viz. glycine, alanine, serine, threonine, valine, aspartic acid and glutamic acid.[2, 3] Not only so, but estimations of the amounts of the substituted acids indicated that the average molecular weight of the polypeptide chains is approximately the same (60,000) in all four types of fibre. The ingenious procedure of Akabori, Ohno and Narita[4] has also been used to identify the amino-acids which provide the terminal carboxyl groups of wool keratin. When wool is heated with anhydrous hydrazine, all the amino-acids except those providing terminal carboxyl groups are converted into hydrazides. The unchanged amino-acids are readily separated from the hydrazides by means of a suitable ion-exchange resin, and it is interesting that the amino-acids which provide the terminal carboxyl groups of merino wool were found to be four of those which provide terminal amino groups, viz. glycine, alanine, serine and threonine.[5]

Unfortunately, little is so far known about the distribution of amino-acids along the length of the polypeptide chains, and attempts to modify the properties of wool by cross-linking reactions have been greatly handicapped for lack of this knowledge. Important information was, however, obtained by Consden, Gordon and Martin[6] in their study of the acidic peptides obtained by the partial acid hydrolysis of wool. Among the dipeptides was a heavy preponderance of glutamylglutamic acid, and this fact, together with the identification of many other polar-polar dipeptides, was

sufficient to invalidate Astbury and Bell's conception[7] of the nature of α-keratin, according to which polar and non-polar side-chains should alternate along the folded polypeptide chains. The need for any such limitation on the arrangement of the amino-acid residues disappeared with Pauling and Corey's suggestion[8] that the chains are spiral in form, with 3·7 amino-acid residues per turn, each residue being hydrogen-bonded to the third from it in each direction along the chain. The nature of the fold is shown in Figure 1. It gives a low value for the density of keratin, but the difficulty is met if the spiral molecules are coiled with one another to form the rope-like structure shown in Figure 2.[9]

FIGURE 2. *Spiral molecules arranged as a 7-strand cable, with a single strand (compound α-helix) of a different pitch on the left. (Reproduced by courtesy of the National Academy of Science from the Academy's Proceedings)*

At this stage in the evolution of our knowledge of the structure of the wool fibre the wheel turns full circle. Whereas the next step would appear to be that of determining the order in which the amino-acid residues are arranged in the polypeptide chains, startling new indications of the extreme heterogeneity of keratin have combined to discourage such investigations. In the first place the cuticle of the fibre has been shown to consist of three phases: the epicuticle,[10] a membrane about 100A thick, which is lifted from the surface of the scales by chlorine water and encloses the Allwörden blisters; the exocuticle; and the endocuticle. The complexity of the cuticle is clearly shown in Figure 3, which is an electron micrograph of a cross-section of pig's bristle after the latter had been stained by treatment with an aqueous solution of sodium plumbite for 18 hours at 35°C.[11] Similarly, the cortex of the fibre is now known to be even more heterogeneous than was at first supposed. The discovery was made by Horio and Kondo,[12] who observed the presence of heavily and lightly dyed segments in the cross-sections of dyed wool fibres, and Mercer[13] subsequently named them the ortho- and para-cortex, respectively. A photograph illustrating the disposition and structural features of the orthocortex and paracortex in a lamb's wool fibre (Carin—mentioned later) is reproduced in Figure 4. It shows the cross-section of a fibre which had been stained by reduction with thioglycollic acid (0·5M) for 18 hours at 35°C., rinsing in alcohol and water, followed by treatment with an aqueous solution of osmium tetroxide (1%) for 1½ days. The orthocortex is clearly differentiated into macrofibrils, whereas the paracortex is not. It is now known that in merino wool fibres the hemicylinders spiral in accordance with the crimp, the orthocortex occupying the outside of each wave. Compared with the paracortex it is deficient in sulphur and less resistant to the action of alkalis and enzymes, as well as to penetration by dyes. Recent electron microscope studies[14] of the fine structure of the cortex have revealed an even greater degree of complexity. When the fibre is stained by treatment with thioglycollic acid

FIGURE 3. *Cross-section of a pig's bristle, after staining with sodium plumbite, showing the complex structure of the many cuticular cells*

and osmium tetroxide, as above, the presence of microfibrils, embedded in a matrix which is much richer in sulphur, is clearly demonstrated. The photograph which is reproduced in Figure 5 shows the greater part of the cross-section of a cell from the paracortex of Carin wool. Besides the darker staining of the cell wall and the nucleus, and the imperfect differentiation of the macrofibrils, there are clear indications of the microfibrils and their various modes of packing. It will be obvious, therefore, that determinations of the amino-acid composition of keratin and of the sequence of amino-acids in the polypeptide chains are likely to have only limited value until the proteins studied are identified with the histological components of the fibre.

The overall amino-acid composition of wool keratin is now known with great precision.[15] Data for various wools are given in Table I:

TABLE I

AMINO-ACID ANALYSES OF FOUR WOOLS

Amino-Acid	*Nitrogen Content as Percentage of the Nitrogen Content of the Wool*			
	64s *Merino*	70s *Merino*	56s *Corriedale*	64s *Merino*
Alanine	3·51	3·51	4·37	4·12
Amide nitrogen ...	7·46*	7·92*	9·27*	6·73
Arginine	20·32	19·35	18·21	19·1
Aspartic acid ...	4·24	4·68	4·86	4·38
Cystine	7·93	6·50	6·80	7·30
Glutamic acid ...	8·58	8·54	9·69	8·48
Glycine	5·80	6·60	6·40	6·29
Histidine	1·46	1·48	1·59	1·91
iso-Leucine ...	1·97	2·13	2·38	2·44
Leucine	4·90	5·37	5·51	5·85
Lysine	3·25	3·19	3·72	3·92
Methionine ...	0·31	0·37	0·37	0·32
Phenylalanine ...	1·75	2·28	2·35	2·12†
Proline	5·33	5·12	5·52	5·05
Serine	7·25	8·63	7·71	8·66†
Threonine... ...	4·61	4·12	4·84	5·12†
Tryptophane ...	1·73	1·38	1·80	0·82
Tyrosine	2·97	3·09	3·11	2·62
Valine	3·57	3·56	4·50	4·16
Total ...	96·94	97·82	103·00	99·39

* Uncorrected for decomposition of serine and threonine during hydrolysis.
† Corrected for loss during hydrolysis.

If Leach and Parkhill's values[16] for the amide nitrogen content of 64s Merino, 70s Merino and 56s Corriedale wool, viz., 6·30, 6·10 and 6·16 per cent, are used in place of the uncorrected values for the first three wools in Table I, the acidic side-chains of all four samples of wool are found to be roughly equivalent to the basic side-chains plus amide nitrogen. The data, which are in conformity with the salt linkage hypothesis,[17] are summarized in Table II:

TABLE II

Wool	*¼ Arginine-N + ½ Lysine N + Amide N*	*Aspartic acid-N + Glutamic acid-N*
64s Merino ...	5·08+1·63+6·30=13·01	4·24+8·58=12·82
70s Merino ...	4·84+1·60+6·10=12·54	4·68+8·54=13·22
56s Corriedale ...	4·55+1·86+6·16=12·57	4·86+9·69=14·55
64s Merino ...	4·78+1·96+6·73=13·47	4·38+8·48=12·86
	Total 51·59	Total 53·45

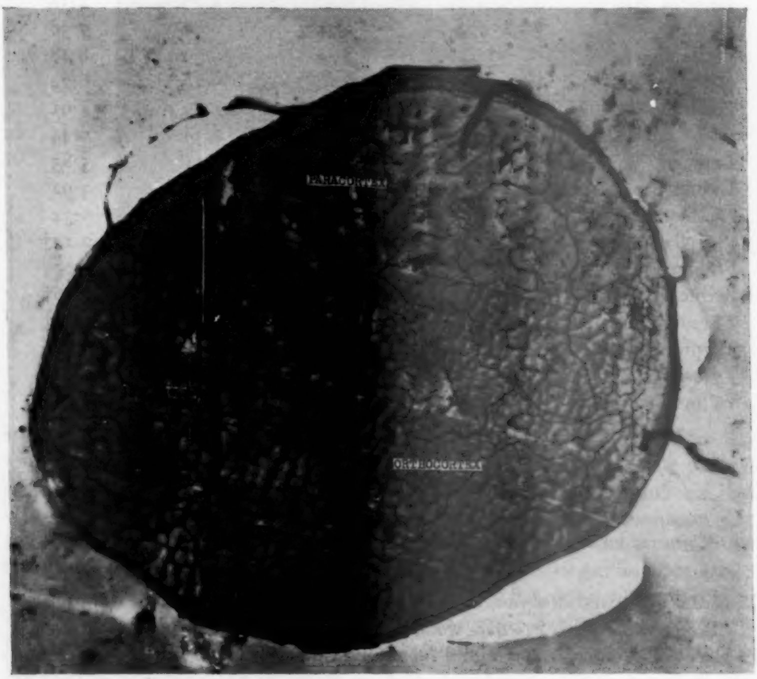

FIGURE 4. *Cross-section of a lamb's-wool fibre, showing differences of structure between the orthocortex and the paracortex*

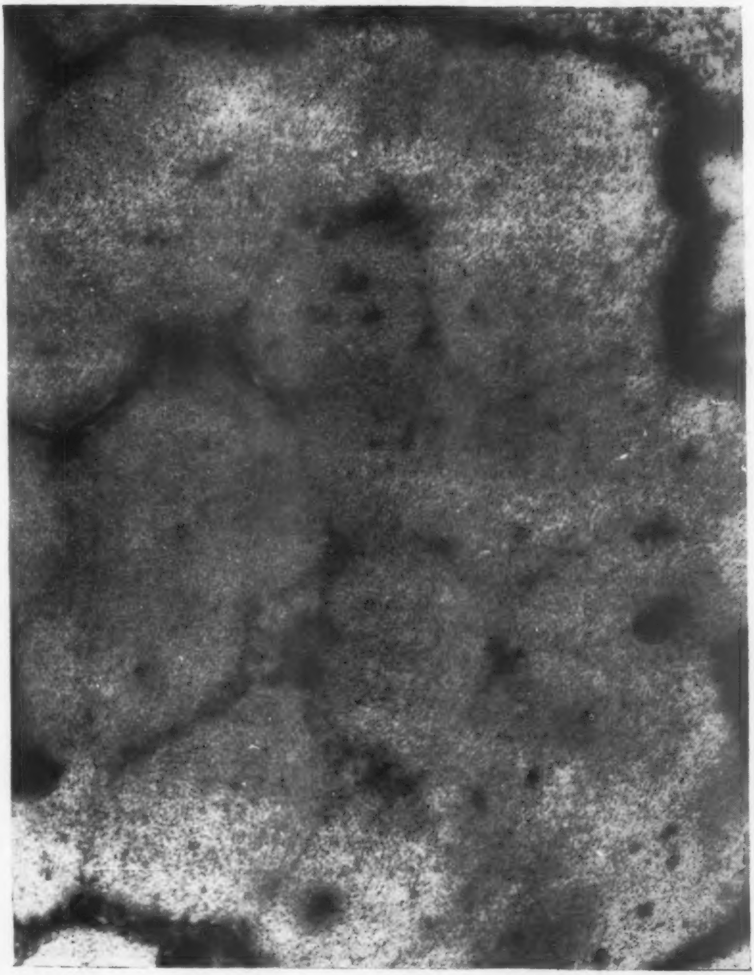

FIGURE 5. *Cross-section of most of a cell from the paracortex of a lamb's-wool fibre*

Even better agreement is obtained if histidine is included among the bases, and it will be interesting to discover whether the acidic and basic portions of the keratin molecule show the same striking similarity of pattern that Schwartz[18] has noted in pig and sheep adrenocorticotropic hormone:

12 13 14 15 16 17 18 19 20 21 22 23
-pro-val-gly-lys-lys-arg-arg-pro-val-lys-val-tyr-
pro-ala-gly-glu-asp-asp-glu-leu-ala-glu-ala-phe-
-ser-
24 25 26 27 28 29 30 31 32 33 34 35

The acidic amino-acids in the bottom chain are found in positions corresponding to those occupied by the basic amino-acids in the top chain.

Unfortunately, the histological complexity of keratin is so great that attempts to determine the amino-acid sequence in the polypeptide chains will have to be postponed until pure preparations of the proteins of well-defined histological components are available. All methods of fractionating the proteins of keratin are, of course, based on reactions which promote disulphide bond breakdown, and the first reagent used was chlorine dioxide.[19] Greater success was obtained with peracetic acid, about 90 per cent of the oxidised protein being soluble in 0·1 *N* ammonia.[20] The insoluble residue has been termed β-keratose, and the

TABLE III

Amino-Acid	*Nitrogen Content as Percentage of the Total Nitrogen of the Fraction*		
	γ-Keratose	*α-Keratose*	*β-Keratose*
Alanine	2·58	4·83	4·84
Ammonia	11·05	10·25	8·61
Arginine	19·0	20·8	17·7
Aspartic acid	1·79	6·25	4·75
Cysteic acid	14·5	3·72	4·40
Glutamic acid ...	5·87	10·9	7·32
Glycine	4·97	5·16	6·53
Histidine	1·57	1·24	2·64
iso-Leucine	2·14	2·49	2·85
Leucine	2·55	7·30	6·17
Lysine	1·03	4·60	6·43
Phenylalanine	1·15	1·94	2·35
Proline	9·85	2·69	4·57
Serine	9·70	6·70	7·99
Threonine	7·46	3·45	4·40
Tyrosine	1·41	2·44	2·25
Valine	4·15	3·98	4·41
Total	100·77	98·74	98·21
Total Nitrogen (%)	13·5	16·0	15·6
Total Sulphur (%)	5·84	1·88	2·13

soluble portion can be divided into two fractions, α- and γ-keratose, by acidification with acetic acid, the former being precipitated. β-keratose seems to consist primarily of cell membranes, and there is now a tendency to regard γ-keratose, which is rich in cysteic acid, as being derived mainly from the matrix surrounding the microfibrils, while α-keratose is tentatively attributed to the microfibrils themselves, which are deficient in sulphur. Recent analyses of the three keratoses, derived from Australian 64s merino wool, are given in Table III.[21] Compared with α-keratose, γ-keratose is rich in cysteic acid, proline, serine and threonine, but deficient in aspartic acid, glutamic acid, leucine and lysine. Keratin has been fractionated also after solubilization by reduction of the cystine linkages,[22] but any attempts to draw conclusions from all such investigations would be unwise at this stage of the work because of uncertainty as to the histological origin of the fractions.

WOOL QUALITY AND ITS ASSESSMENT

In view of the extreme complexity of the structure and composition of wool, it is not surprising that the assessment of 'quality' in wool is made by the visual and tactile judgement of experts, rather than by scientific means. Among the more obvious factors which affect quality are the fineness, length and crimp of the fibres, as well as their uniformity in these respects. So great is the importance attached to fineness of fibre that it has come to be assumed, in countries where the craft of quality assessment is less well developed than in the United Kingdom, that each quality can be associated with a particular diameter of fibre. And since the average fibre diameter of a sample of wool can be determined rapidly by measuring the rate of flow of air through a plug of fibres, there is a growing desire to replace the visual and tactile judgement of quality by a determination of average fibre diameter. It should, however, be recognized that any such procedure is based on one or other of the following assumptions: either that the nature of the substance of the fibre is unimportant, or that all wools are composed of the same substance. Were the former assumption valid, it would be immaterial, as regards processing, whether the fibres were composed of keratin, cellulose or nylon, so long as their dimensional characteristics were the same, and this is clearly nonsense. As regards the second assumption, the preceding discussion of the complexity of the wool fibre makes it improbable that the substance of all types of wool is the same, and much evidence has been accumulated recently to show that there are not only variations in substance but that such variations are of great commercial importance.[23]

During the course of his recent lecture on 'Scientific Measurement in Commercial Practice' to the Bradford Textile Society, Mr. T. Hunter[24] exhibited two tops, one made from New Zealand wool and the other from South American (B.A.) wool. Without exception the trade experts had assessed the New Zealand top as a 50s and the B.A. top as a 46s. When, however, measurements of fibre diameter were made, the two tops were found to be remarkably alike as regards both mean diameter and diameter distribution. The results of 400 measurements on each top are given in Table IV:

TABLE IV

Wool	*Mean Diameter* (μ)	*Coefficient of Variation* (%)
N.Z. 50s	34·9	25·8
B.A. 46s	33·3	27·5

It is obvious, therefore, that fibres of the same diameter do not necessarily have the same quality, and it becomes necessary to decide what factors, other than fineness of fibre, affect the judgement of the expert. In the case under discussion, it is possible that the greater, though small, amount of crimp in the New Zealand wool may have affected the assessment of quality, but in the light of the preceding argument it becomes necessary to discover whether there are differences of substance which are detected by the tactile judgement of the expert.

The most sensitive means of detecting differences between wool fibres is their plasticity, and since the plasticity of wool plays an important part in yarn production and many finishing processes, it has the additional merit of being closely linked with the behaviour of wool during processing, a factor which may be particularly important in the assessment of quality if the expert has, through his experience, come to associate the appearance of a wool with its behaviour during processing, that is, if he has come to 'recognize' a wool in much the same way as he 'recognizes' an acquaintance. The one kind of recognition may be just as precise as the other, even though both defy description.

Plasticity measurements were, therefore, made on 50 fibres from each of the two tops. The procedure[23] consisted simply in measuring the rate of extension of single fibres in distilled water at 22·2°C. under a load of 6 kg./mm.^{2} When log $(E - E_t)$ is plotted against t, E_t being the percentage extension at time t (minutes) and E an arbitrarily chosen limiting extension, a linear relationship is obtained in the later stages of extension. The slope (k) of the line gives a simple measure of plasticity, and values for the two tops are given in Table V.* There are clearly important differences of substance between the two wools, and it appears that the expert in these cases prefers the more plastic, that is, the better handling, wool.

By itself alone the case of the two tops is, of course, insufficient to establish whether the expert does detect differences in the substance of different wools. Through the kindness of Mr. K. G. Ponting, a woollen manufacturer in the West of England, two samples of lambs' wool were next brought to our attention. About one of these (Carin–Victoria) he inquired why it should command such a fantastic price—more than double that of the other (Pindabunna–Western

* The results given in Tables V, VI, VII and VIII form part of a larger investigation, carried out in conjunction with Mr. K. J. Whiteley, which will be reported in detail elsewhere.

TABLE V

E = 70%	
Wool	*k* (*arbitrary units*)
N.Z. 50s ...	30·0
B.A. 46s ...	15·2

Australia). He believed that it was because it was specially suitable for blending with cashmere. Diameter measurements (300 fibres) showed that the Carin wool was considerably finer ($17{\cdot}3\mu$) than the Pindabunna wool ($20{\cdot}6\mu$), but, in addition, the Carin wool was very much more plastic. The results are given in Table VI:

TABLE VI

E = 80%	
Wool	*k* (*arbitrary units*)
Carin	78·6
Pindabunna ...	27·1

Unfortunately, the difference in fineness of the two wools makes it impossible to determine the extent to which differences of substance govern the preference for Carin wool.

Eight further samples of wool were, therefore, obtained from Mr. Ponting. Their characteristics, which were determined without knowledge of his opinion of the wools, are given in Table VII.

When these results were available it was disclosed that the two of highest plasticity—127 and 10—brought prices about three times those of the remaining wools, despite the fact that 127 is so much coarser than the remainder. Both wools were bought for blending with cashmere, and of the two 10 was regarded as the better, presumably because of combined fineness and high plasticity.

The preference for wools of high plasticity for products where excellence of handle is essential was confirmed with wools provided by a Scottish manufacturer of high-class woollen overcoatings. A case of a different kind is that of a Bradford topmaker, who had observed that in blending South American and Australian wools, the former was matched with a coarser Australian wool because of its greater 'inherent resilience'. Five samples were submitted, the Concordia wool

TABLE VII

E = 80%		
Wool	*Mean Diameter* (μ)	*k* (*arbitrary units*)
127 Lambs' wool—Victoria	23·4	53·6
10 Lambs' wool—Victoria	18·6	45·3
31 Lambs' wool—Kenya	20·8	43·5
52 Tasmanian (clothing)	16·6	37·8
58 Lambs' wool—Cape	15·4	37·6
64 Lambs' wool—Queensland	17·3	37·1
22 Queensland (Weavers)	18·2	29·5
109 Western Australia (AA Weavers) ...	17·8	21·9

TABLE VIII

E = 80%		
Wool	*Mean Diameter* (μ)	*k* (*arbitrary units*)
Australian 64s	19·8	65·1
Australian 58s	30·6	40·0
Montevideo 64s	24·9	33·3
Montevideo 58s	37·4	19·5
Concordia 58s	27·1	13·5

being one that was difficult to match with an Australian wool. The results obtained with these samples are given in Table VIII. In agreement with earlier results the striking fact emerges that the wool which presents the greatest difficulty (Concordia) is by far the least plastic.

All such measurements of plasticity combine to show that there are marked differences of substance between wools, and that the differences are detected and used to great advantage by the wool textile industry. Skill in selecting the wools which are best suited for particular purposes is the basic reason for the

excellence of British woollens and worsteds, and it is not surprising, therefore, that there should be a reluctance to blend man-made fibres with wool. But the advent of man-made fibres has led to shortened systems of converting staple fibre into yarn, and the production of truly synthetic fibres, such as the polyamide, polyester and polyacrylonitrile fibres, has transformed the consumer's conception of what is to be expected of a textile material as regards serviceability. Garments made of the synthetic fibres are hard-wearing, preserve their shape during laundering, dry quickly afterwards, and do not need ironing: 'easy care' materials. In addition, the thermoplastic nature of the fibres allows a number of novel effects and finishes to be obtained. The wool textile industry has not been slow to meet the challenge offered by these developments, and some aspects of its response will now be discussed.

TECHNICAL DEVELOPMENTS

(*a*) *Yarn Manufacture.*—The 'tow-to-top' systems of processing man-made fibres, in which an assembly of continuous filaments is converted directly into top in a single cutting operation, offers a striking contrast to the lengthy series of processes in the worsted industry: scouring, carding, backwashing, gilling (twice), combing, and gilling (twice). Even simpler is the Perlok system of converting continuous filament yarn directly into a staple fibre yarn, and shortened methods of processing natural fibres which begin their existence as staple fibre will have to be evolved if such natural fibres are not to suffer always from the disadvantage of higher costs of processing. A solution to the problem is of much greater importance to the worsted industry than to the cotton industry, and it is, therefore, encouraging that there has been a renaissance of inventiveness in the worsted industry since the end of the Second World War. The autoleveller developed by Mr. G. F. Raper[25] and the Superdraft system of spinning invented by Air Vice-Marshal G. Ambler[26] have been combined to give a shortened system of worsted drawing and spinning. Both inventions came from within the industry, and although the new system does not bring exclusive benefit to wool—it can, of course, be used with all types of fibre—the development is important in relation to the main problem which has still to be faced, because the long-established systems have in one section of the field at least been challenged and overthrown.

(*b*) *Finishing.*—Before recent developments are discussed, mention must be made of the fact that two important aspects of 'easy care' finishes for wool had been dealt with before the term 'easy care' was invented. These are the anti-shrink and mothproof finishes. Once the skeleton structure of the wool 'molecule' had been defined and the action of chlorine on wool interpreted, there followed a series of new methods of making wool unshrinkable; all of them depend for their success on disulphide bond breakdown in the surface of the fibres, and many of the methods have the advantage of leaving the handle of the material sensibly unimpaired. Until recently, permanent mothproof finishes for wool were generally obtained with colourless compounds, which, besides being specific poisons for moth larvae, were similar in constitution to acid dyes and were

applied from the acid dyebath. A simpler and cheaper procedure is now available.[27] It consists simply in applying 0·05 per cent (on the weight of the wool) of Dieldrin in the form of an aqueous emulsion.

Among new developments are the methods of imparting permanent creases and pleats to all-wool fabrics. The evolution of these processes was prompted by the fact that fabrics made from blends of Terylene staple fibre and wool (55:45) can be given creases or pleats which are resistant to both dry-cleaning and washing by simple treatment with superheated steam. When, however, an all-wool fabric is formed into pleats between pleating papers and steamed for 20 minutes at atmospheric pressure, as is customary, the pleats disappear during dry-cleaning and even more quickly during washing. Similarly, the creases imparted to all-wool trousers during pressing in the Hoffman press are not resistant to either dry-cleaning or washing. It is, however, known that reagents such as alkalis, sulphites and bisulphites act as powerful assistants in setting processes, and simple methods of using them to obtain permanent creases and pleats in all-wool fabrics have been evolved.[28] The most successful is one in which the manufacturer treats the fabric with a 2 per cent solution of sodium bisulphite for 15 minutes at room temperature. At the end of this time, excess bisulphite is removed by rinsing, and the fabric is then centrifuged and dried at a low temperature. The process can be combined with London Shrinking, and the dried fabric is finally pressed between press papers. To obtain permanent creases with the treated fabric the tailor has merely to steam in the Hoffman press in the usual way, preferably with the fabric between damp cloths.

An illustration of the success of the process is afforded by the data of Table IX,[29] which were obtained with one of the more difficult types of fabric, a 16-oz. Scotch tweed. Several samples were treated with bisulphite solutions of different concentrations, followed by rinsing and drying under the conditions already outlined. Strips of the fabric were then folded and steamed for various times, with and without the addition of water, in the Hoffman press. Each strip

TABLE IX

Time of Pressing (seconds)	*Angle of Crease of Samples treated with Bisulphite Solutions of the following Concentrations*					
	Untreated	1%	2%	3%	4%	5%
5 (dry) ...	—	119	110	110	106	106
15 (dry) ...	—	117	109	108	104	103
15 (wet) ...	130	92	95	94	90	93
60 (dry) ...	—	99	100	99	101	98
60 (wet) ...	120	84	87	88	89	90

was afterwards soaked for 3 hours in a solution of Teepol (0·3 per cent.), rinsed, and then allowed to dry freely while held by one edge. Finally, the angle of the residual crease was measured with the Shirley Crease-Resistance Tester. Under all conditions the bisulphite-treated fabrics give much sharper creases than the untreated, and if the fabrics are dried at room temperature after treatment with sodium bisulphite, the concentration of the solution need not be more than 1 per cent. When drying is carried out in a tentering machine at a temperature which must be below 80°C., the concentration should be higher (2 per cent), for reasons which will be apparent from the nature of the setting reactions.

When wool is treated with sodium bisulphite solution, disulphide bond breakdown takes place as follows:

$$R\text{-}S\text{-}S\text{-}R + NaHSO_3 \longrightarrow R.SH + R.S.SO_3Na$$

Although there is some reversal of the reaction during rinsing, much of the bisulphite remains in combination with broken disulphide bonds. When, however, the fabric is steamed in the Hoffman press, disulphide bonds are reformed, and the liberated bisulphite (or sulphur dioxide) is free to break and remake other disulphide bonds elsewhere in the structure. But since the complete process of disulphide bond breakdown and rebuilding takes place with the fabric creased, the crease is made permanent. It seems clear that better results are obtained with wet fabric than with air-dry fabric because the presence of water not only facilitates relaxation by hydrogen-bond breakdown but also promotes migration of sodium bisulphite and sulphur dioxide through the structure.

In the alternative process which has been developed in Australia,[30] the fabric is sprayed with a solution of ammonium thioglycollate by the tailor himself, formed into creases, and then steamed for 15–20 seconds in the Hoffman press. The mechanism of the reaction is similar to that with bisulphite, viz. disulphide bond breakdown and rebuilding

$$R\text{-}S\text{-}S\text{-}R + HS.CH_2.COONH_4 \longleftrightarrow R.SH + R.S.S.CH_2.COONH_4$$

and a 1 per cent solution of sodium (or other) bisulphite can be used in place of ammonium thioglycollate.

Treatment with bisulphite, followed by rinsing, can likewise be used to give permanence to the embossed effect which is imparted to cut and uncut pile fabrics by steaming in contact with a patterned matrix. Setting reactions generally have also been developed recently to give a high permanent lustre to all-wool fabrics. In one process,[31] the fabric is impregnated with a 1 per cent solution of sodium bisulphite in a mixture of equal parts of ethylene glycol and water. When the fabric is afterwards pressed in contact with a heated polished metal surface, the high lustre obtained (Figure 6) is not removed in water or steam because the fibres in the smoothed surface have been set permanently in their deformed shapes.

Progress in the finishing of wool textile materials is not, however, confined to the many applications of setting reactions. Resin finishes are at last finding commercial application, one of the more recent being the oil- and grease-resistant

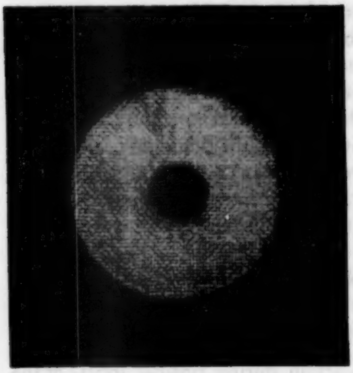

FIGURE 6. *A ring of lustre produced by applying heat and pressure to an all-wool fabric impregnated with a solution containing ethylene glycol and a setting agent*

finish imparted to fabrics, such as the all-wool gaberdine, by means of fluorine-containing resins.

Finally, reference may be made to the discovery of Peters and Stevens[32] that the rate of dyeing of wool under any given conditions may be increased, or the temperature of dyeing for a given time of dyeing reduced, if the dyebath is saturated with a sparingly soluble organic solvent, such as butyl alcohol. The process has already found application in the printing of blankets, the printing paste in this case being saturated with the solvent. After being printed, the blanket is passed through a steamer and the whole process is completed in three minutes.

In the light of these examples there can be no doubt that the chemical finishing of wool is in its infancy. Unrivalled in complexity and versatility, the fibre seems destined to excite the interest, originality and inventiveness of both scientist and technologist until the evolutionary process does provide a substitute for wool.

Acknowledgment

The author is indebted to Dr. J. Sikorski and Mr. W. S. Simpson for the electron micrographs which are reproduced in Figures 3, 4 and 5.

REFERENCES

1. F. Sanger, *Biochem. J.*, 1945, **39**, 507.
2. W. R. Middlebrook, *Nature*, 1949, **164**, 501.
3. J. Tibbs, Ph.D.Thesis, Leeds University, 1951.
4. S. Akabori, K. Ohno and K. Narita, *Bull. Chem. Soc. Japan*, 1952, **25**, 214.
5. S. Blackburn and G. R. Lee, *J. Text. Inst.*, 1954, **45**, T487.
6. R. Consden, A. H. Gordon and A. J. P. Martin, *Biochem. J.*, 1949, **44**, 548.
7. W. T. Astbury and Florence O. Bell, *Nature*, 1941, **147**, 696.
8. L. Pauling and R. B. Corey, *J. Amer. Chem. Soc.*, 1950, **72**, 5349 ; L. Pauling, R. B. Corey and H. R. Branson, *Proc. Nat. Acad. Sci.*, 1951, **37**, 205.
9. L. Pauling and R. B. Corey, *Nature*, 1953, **171**, 59.
10. J. Lindberg, B. Philip and N. Gralén, *Nature*, 1958, **182**, 458.
11. J. Sikorski and W. S. Simpson, *Nature*, 1958, **182**, 1235.
12. M. Horio and T. Kondo, *Text. Res. J.*, 1953, **23**, 373.
13. E. H. Mercer, ibid., 1953, **23**, 388.
14. R. D. B. Fraser, T. P. Macrae and G. E. Rogers, *Nature*, 1959, **183**, 592.
15. D. H. Simmonds, *Proc. Int. Wool Text. Res. Conference*, 1955, C 65 ; M. C. Corfield and A. Robson, *Biochem. J.*, 1955, **59**, 62.
16. S. J. Leach and Evelyn M. J. Parkhill, *Proc. Int. Wool Text. Res. Conference*, 1955, C 92.
17. J. B. Speakman and Mercia C. Hirst, *Trans. Faraday Soc.*, 1933, **29**, 148.
18. D. Schwartz, *Nature*, 1959, **183**, 464.
19. B. Nilssen and J. B. Speakman, *see* J. B. Speakman, *J. Text. Inst.*, 1941, **32**, T83.
20. P. Alexander and C. Earland, *Text. Res. J.*, 1950, **20**, 298.
21. M. C. Corfield, A. Robson and Barbara Skinner, *Biochem. J.*, 1958, **68**, 348.
22. J. M. Gillespie and F. G. Lennox, *Biochim. Biophys. Acta*, 1953, **12**, 481.
23. O. Ripa and J. B. Speakman, *Text. Res. J.*, 1951, **21**, 215 ; R. W. Burley and J. B. Speakman, ibid., 1953, **23**, 702 ; P. L. le Roux and J. B. Speakman, ibid., 1957, **27**, 1.
24. T. Hunter, *J. Bradford Text. Soc.*, 1956-7, p. 88.
25. G. F. Raper, British Patent No. 656,135.
26. G. H. Ambler and Margaret Hannah, *J. Text. Inst.*, 1950, **41**, P115.
27. M. Lipson and R. J. Hope, *Proc. Int. Wool Text. Res. Conference*, 1955, E 523.
28. J. B. Speakman, British Patent No. 775,486.
29. J. B. Speakman and Maria A. Wolfram, in the press.
30. M. Lipson, *Research*, 1959, **12**, 122.
31. J. B. Speakman and Maria A. Wolfram, *J. Text. Inst.*, 1958, **49**, T627.
32. L. Peters and C. B. Stevens, *The Dyer*, 1956, **115**, 327 ; *J. Soc. Dyers and Colourists*, 1956, **72**, 100, 241 ; L. Peters, ibid., 1957, **73**, 23.

II. RESEARCH IN COTTON

by

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INTRODUCTION

Cotton is, and has been for a long time, the world's most important industrial fibre, whether its importance be measured by the weight of fibre produced or by its value. The latest figures available[1] are in Table I, from which it is seen that in 1956–7 cotton accounted for about one-half by weight, and two-fifths by value, of all the industrial fibres produced; the current position is not likely to be materially different.

TABLE I

ESTIMATED TOTAL WORLD PRODUCTION OF INDUSTRIAL FIBRES 1956–7

FIBRE	*Weight* (10^8 *lb.*)	*Approx. av. price in U.K. in pence per lb.*	*Approx. value* (10^8 £)
Cotton	188	26	20
Wool	29	90	11
Rayon filament yarn ...	22	60	6
Man-made fibres (non-rayon)	7	120	4
Flax	32	30	4
Rayon staple fibre ...	30	24	3
Silk	1	400	2
Jute	40	10	2
Hemp	26	8	1
TOTAL ...	375	—	53

It is not surprising therefore that since governments and industries became 'research-conscious'—an era which may be conveniently but arbitrarily taken as beginning in 1920—a vast amount of research has been undertaken in all parts of the globe into the growing and breeding of cotton, into the physical and chemical structure of the fibre, into its properties, and into the mechanical and

chemical treatments by which the fibres are converted into yarn and finished cloth. It is the research carried out during this period that I propose to review in this lecture.

Since there seems to be no reason for excluding any particular field from consideration, I propose, after a brief mention of research organizations, to deal with each section in turn, starting with the growing of cotton and ending with the finishing of cloth. Hence, in the time at my disposal I shall be unable to do more than describe broadly some of the main topics of research; but to remedy this deficiency I have given references to the literature which enable any point of interest to be pursued further.

RESEARCH ORGANIZATIONS

One of the earliest cotton research organizations and now the most important in the world, is the Shirley Institute, the headquarters of the British Cotton Industry Research Association (Figure 1). Named after the daughter of an early

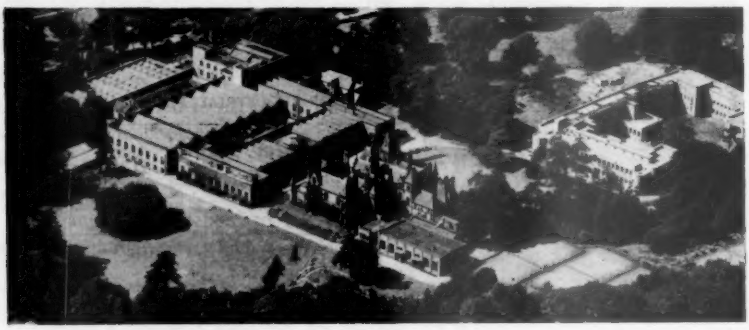

FIGURE 1. *The Shirley Institute, headquarters of the British Cotton Industry Research Association, situated at Didsbury, Manchester. (Photograph by courtesy of Aero Pictorial Limited)*

benefactor and situated at Didsbury, Manchester, it was founded in 1919 as one of the co-operative industrial research associations sponsored, but only partially maintained, by the Department of Scientific and Industrial Research. Directed successively by the late Dr. A. W. Crossley, the late Sir Robert Pickard, Dr. F. C. Toy and Dr. D. W. Hill, the Shirley Institute has steadily expanded until it now has a total staff of 450 (of whom 160 are graduates), 170,000 square feet of laboratory, workshop and office floor-space and an annual expenditure of over £400,000. There are few aspects of the subject that have not been touched upon by the Institute in the course of its forty years of existence. To-day, however, it is no longer concerned directly with growing and breeding cotton; on the other hand, its interests have been extended to embrace all fibres that can be processed on cotton machinery.

Within the British Commonwealth, research into growing and breeding is undertaken by the Empire Cotton Growing Corporation, which collaborates closely with the Shirley Institute. The E.C.G.C.'s administrative headquarters is in London, but its main research station, formerly located in Trinidad, is now at Namulonge in Uganda. Research of a similar kind is fostered by agencies of various types in all the important cotton-growing countries: in the United States by the Department of Agriculture, though important work is also done by universities and private firms; in Egypt by the Cotton Research Board; in India by the Central Cotton Committee; and so on.

Research is even more widespread on the properties of raw cotton, cotton yarn and fabric, and on the manufacturing processes for which cotton is the raw material. In the United States research of this kind is undertaken at the Southern Regional Research Laboratory of the Department of Agriculture, the Textile Research Institute, Fabric Research Laboratories Inc., North Carolina State College and other colleges, besides the research departments of many large private firms; in France, at l'Institut Textile de France; in the Netherlands, at the Wezelinstituut T.N.O.; in Sweden, at the Textilforskning Institutet; in India, at the Ahmedabad Textile Industries Research Institute; and at many others.

In Great Britain important work is also done outside the Shirley Institute, in the laboratories of firms such as Fine Spinners Ltd., Tootals Ltd., and the Calico Printers' Association, and at the Colleges of Science and Technology at Manchester and Glasgow. The Research Department of Fine Spinners Ltd. calls for especial mention. Founded in 1915 (so predating the Shirley Institute), as the Experimental Department of the Fine Cotton Spinners' and Doublers' Association Ltd. (as the firm was then called), it was directed during its first decade by Lawrence Balls, who, because of his ingenuity and versatility, might aptly be called the Leonardo da Vinci of cotton research. His book, *Studies of Quality in Cotton*[2], which describes the work done there, has for long stimulated research and development in cotton growing, spinning and testing.

THE COTTON PLANT

Forty years ago the botanical classification of the genus *Gossypium*, to which cultivated cotton plants belong, was far from satisfactory. The difficulties were of more than theoretical interest; they bore on such practical problems as why American or Eygptian cotton could not be crossed with a true Indian cotton. Research in the intervening period has removed many of the difficulties and has led to a revised classification.

One main line of investigation was initiated by Denham[3] in 1923 when, working on cotton grown in the greenhouse at the Shirley Institute, he was the first to discover that Old World and New World cultivated cottons were differentiated by having haploid numbers of chromosomes of 13 and 26 respectively. According to Zaitzev[4] the same discovery was made independently by Nikolajeva working in Russia at about the same time. Following this, many more cytological studies, both on cultivated cottons and on wild species, were made by Vavilov and

Zaitzev in Russia, Harland in Trinidad, and by Kearney, Langley, and others in the United States.

Another line of attack, initiated by Vavilov,[5] made use of the geographical distribution of different varieties of cotton. Collections of world cottons were therefore assembled for study and experiment in several centres: at Tashkent by Vavilov, at Trinidad by Harland, at Indore by Hutchinson, in California

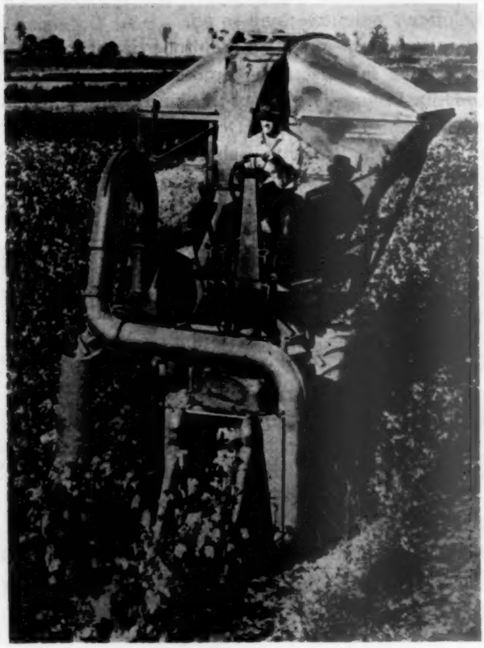

FIGURE 2. *The mechanical picking of cotton. (Photograph by courtesy of the Cotton Board)*

by Kearney, and in North Carolina and, later, Texas by Beasley. The upshot of this activity was the publication in 1947 of a revised classification of the genus *Gossypium* by Hutchinson, Silow and Stephens,[6] dealt with from the evolutionary standpoint and giving due weight to cytological, genetic, geographical and archæological evidence.

The foregoing research is closely related to that on the breeding of cotton, much of which has indeed been done by the same individuals at the same research centres. The work of Knight[7] in the Sudan must, however, not be overlooked.

The cotton-grower is always seeking seed that will give a higher yield, a plant more resistant to specific diseases, or lint more acceptable to the spinner, or improved in any one of dozens of possible ways. The problem is exceedingly complex—Brown and Ware[8] list 56 characters of interest, excluding resistance to disease or insect attack—but much has been done by the systematic application of genetical principles. Harland,[9] formerly of the Shirley Institute and the E.C.G.G., has been a leading worker in this field. An interesting example of the application of genetics is the use that has been made of a wild cotton, *Gossypium thurberi*, which, though producing naked seeds, possesses a gene for strength in fibre and so is of value for crossing with cultivated varieties suffering from weak fibre.[10]

The conditions under which the cotton plant is grown have also been widely studied. In *The Yields of a Crop*, Balls[11] describes his researches on the effects on the Egyptian cotton crop of the water supply, the height of the water-table, temperature, fertilizers and insects. This work may be taken as typical, though the emphasis on different aspects varies from one cotton-growing area to another.

This section may be appropriately closed with a reference to the mechanical harvesting of cotton, a task which for difficulty has been compared with the attempt to gather strawberries or raspberries by machine. It is not surprising, therefore, that, though it takes about 100 hours for one person to pick a bale (478 lb.) of cotton (and there may be 15 million bales to be picked in the United States in one season) and though attempts had been made at least since 1850 to harvest the crop mechanically, little progress was made until 1940; but since then progress has been rapid and by 1955, 23 per cent of the United States crop was mechanically harvested. Driving one of these machines a man may, in favourable circumstances, harvest a bale of cotton in half an hour (Figure 2).

The plants are defoliated in advance by dusting with calcium cyanamide or spraying with certain other chemicals. Much research, initiated by Hall and Harrell[12] in South Carolina in 1938, has been done on the factors controlling the effectiveness of these applications. A new problem now arises for the breeder: how to produce a variety of cotton with the bolls ripening and opening all at the same time and advantageously disposed for collection by the mechanical picker.

MOLECULAR STRUCTURE OF COTTON CELLULOSE

Since in typical instances 94 per cent by weight of oven-dry cotton lint consists of cellulose, the research that has largely succeeded in describing satisfactorily the structure of cellulose may properly be considered here. At the beginning of the period we are reviewing it was a matter for conjecture and controversy.[13] It was known that cellulose was related to glucose, but the structure of glucose was still uncertain. A big step forward was therefore made when Haworth and his co-workers[14] established the structural formula of glucose in 1925. This initiated an intensified attack on the cellulose problem by the methods of sugar chemistry. A little earlier X-ray analysis was brought to bear on the problem by Herzog and Jancke[15], followed by Sponsler and Dore[16] in 1926, and Meyer and Mark[17] in 1928. A third line of attack was that of Staudinger of Freiburg

University, derived from work on synthetic polymers and the viscosity of polymer solutions.

The progress of the campaign was reviewed in 1936 by Davidson,[18] who showed how the work of the Shirley Institute on the action of acids and oxidizing agents on cotton cellulose could be theoretically interpreted in the light of the new theory. This work,[19] which is still continuing, has led to a much better understanding of the nature of the chemical damage that cotton may suffer during chemical processing or in use.

The view generally held to-day about how the cotton hair is built up in successive stages from glucose residues, crystallites and fibrils, is described by

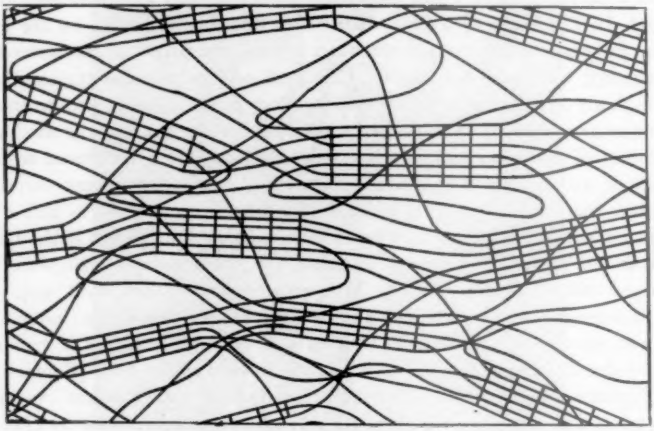

FIGURE 3. *Diagram illustrating the grouping of cellulose molecules in the cotton fibre to form crystalline and amorphous regions*

Brown and Ware[20] along the following lines. The cellulose molecule consists of a polymerized chain of 5,000 to 10,000 glucose anhydride units held together by primary valencies, the longest molecule being about 5 microns long. The molecules lie roughly parallel to each other, being more so in some places and less in others. Where the chains are truly parallel they are held in position by secondary valencies and form crystallites. The number of molecules running alongside each other in this way may be 50 to 100. Where the chains diverge so much that the effective bonding distance is exceeded the structure is amorphous. A single molecule may pass from one crystallite into an amorphous region and then into another crystallite (Figure 3). In a dried cotton hair at least 70 per cent of the total cellulose is in the crystalline condition. Groups of crystallites in turn form fibrils and the resulting fibrillar structure, following a helical path which reverses at intervals, can be seen under the microscope.

MEASUREMENT OF THE PHYSICAL CHARACTERS OF COTTON FIBRES

A spinner, when buying raw cotton, must be certain that it is of the right staple length to match his machinery, that it is suitable generally for the class of yarn he aims at spinning, and appropriate to the particular count to be spun. Until recently this assessment was almost invariably a matter of subjective judgement, although a battery of appropriate laboratory tests had been worked out by Clegg[21] as long ago as 1931, but these tests took too long for commercial use. The time factor is particularly important when making the initial classification of a whole cotton crop, bale by bale. Later research has, therefore, been concentrated on the development of methods for the *rapid* objective measurement of those characters of raw cotton of interest to the spinner, with a view to supplementing or even superseding some of the subjective tests. These tests have been developed mainly in the United States.

One class of test makes use of the resistance imposed to the flow of air by a plug of cotton fibre. From this figure the surface area per unit mass may be obtained and, with the aid of additional evidence about the dimensions of the fibre cross-sections, the thickness of the cell-wall or the degree of maturity of the cotton may be deduced. One instrument of this type which has become commercially acceptable is the Micronaire.[22]

The objective determination of staple length has been accelerated by the use of photo-electric methods, as in the Fibrograph due to Hertel[23] and the Shirley Photo-electric Stapler.[24] Measurement of fibre strength has been speeded up by measurement on a prepared bundle of lint, as in the Pressley strength tester.[25]

OPENING AND CLEANING

Cotton comes to the spinning mill in a highly compressed state and the problem is to open it up, without damaging it, to such an extent that the cotton can be separated from the trash by making use of the difference in buoyancy in air between small tufts of cotton and the various kinds of foreign matter present. The introduction of mechanical harvesting, which produces dirtier cotton than hand picking, has caused increased emphasis to be placed on cleaning methods.

The opening machines in general use were evolved by trial and error and the factors governing their performance were, for a long time, not properly understood. If a spinner wished to clean his cotton more thoroughly he merely added another opener of the same general type to his line, a practice which was later shown to be very inefficient by Shorter, Williams and Peirce[26] at the Shirley Institute. They showed, as the result of surveys carried out in mills and aerodynamic studies made in the laboratory, that the cotton should be opened up progressively into smaller and smaller tufts if the cleaning were to be improved. The results have been applied industrially in the Shirley Opener, a machine of greatly improved cleaning capacity which replaces several of the older, less efficient machines previously employed in tandem. The principle underlying it is also applied in the Shirley Analyser, an instrument for separating

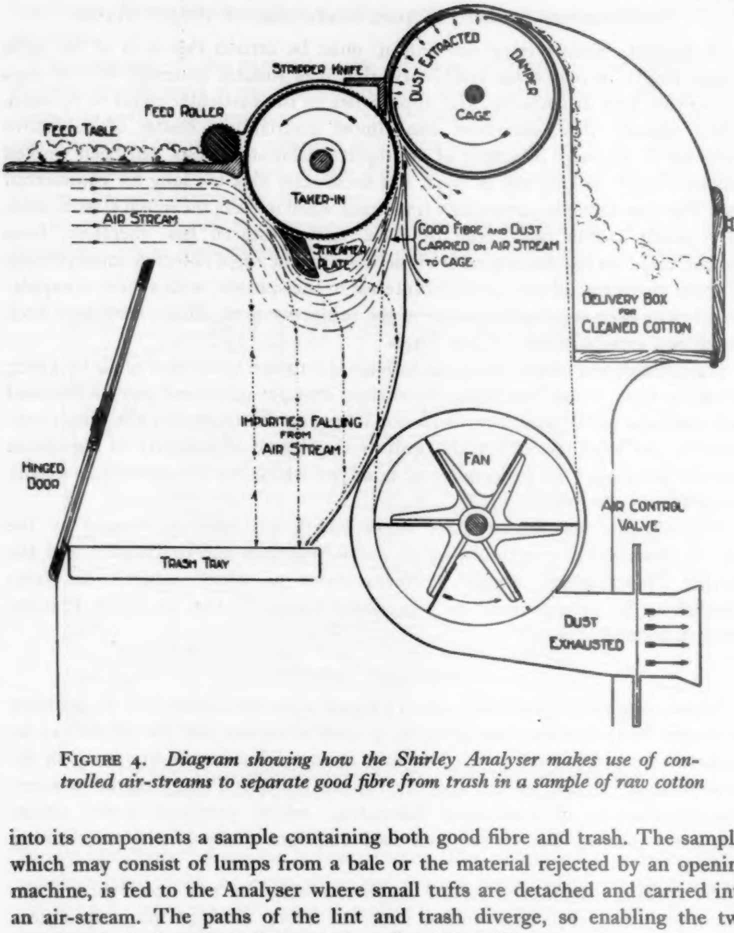

FIGURE 4. *Diagram showing how the Shirley Analyser makes use of controlled air-streams to separate good fibre from trash in a sample of raw cotton*

into its components a sample containing both good fibre and trash. The sample, which may consist of lumps from a bale or the material rejected by an opening machine, is fed to the Analyser where small tufts are detached and carried into an air-stream. The paths of the lint and trash diverge, so enabling the two components to be collected separately and weighed (Figure 4).

There is no time to speak of the next process, carding, a field in which much research remains to be done, other than to mention that as a result of research, mainly done at the Shirley Institute, progress is at last being made with the long-standing problem of the avoidance of dust in card-rooms.

SPINNING

The sliver or rope of fibres emerging from the card needs to be attenuated and the fibres in it made roughly parallel before it is twisted to form a yarn. These aims are achieved by means of roller-drafting, a process which has been

the subject of much research, directed mainly to explaining the variability in linear density that arises and finding ways to minimize it. Balls[27] was early in the field with his discovery of the *drafting-wave*, a feature which he showed to be inherent in the process of drafting a sliver of fibres of widely different lengths. More recent and detailed studies of the properties of the drafting-wave have been made by Foster.[28]

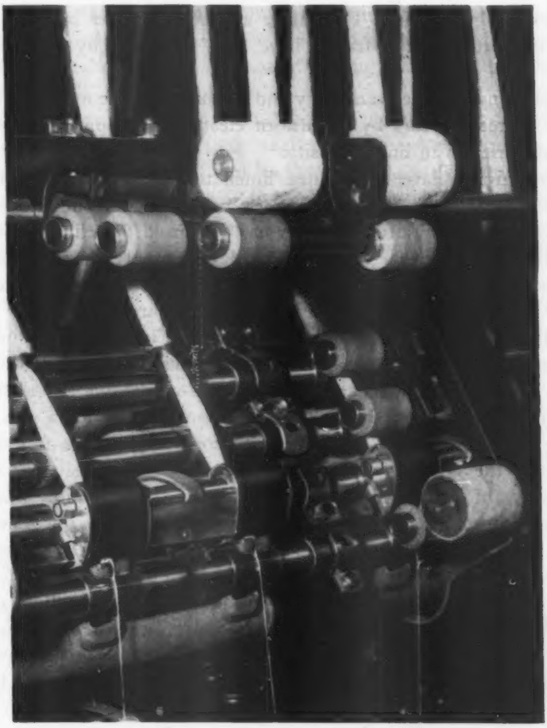

FIGURE 5. *The high-drafting system of a ring-frame used for spinning yarn directly from draw-frame sliver. (Photograph by courtesy of the* Textile Recorder)

More important from a practical standpoint, since more can be done about it, is the appreciation that apparently insignificant machinery imperfections may lead to serious irregularity in the yarn. These imperfections are of three main kinds: (*a*) the position of the roller nip may vary; (*b*) the rollers may not run at steady speeds; (*c*) top rollers may slip. Variation in the position of the nip has been investigated by Gregory and Tyson[29] and has been shown to be due mainly

to eccentricity of the rollers; that is, their geometrical axes do not coincide with the axes about which they are rotating. An eccentricity of no more than two-thousandths of an inch may in certain circumstances be undesirable.

Variable speed of rotation may arise from defects in the gearing, such as incorrect tooth profile or eccentric mounting of wheels, or to torsional vibration. These aspects of the problem have been investigated by Gregory.[30] Torsional vibration, however, still gives trouble and no sure method of avoiding it completely has yet been found. The causes and consequences of roller slip, which occurs mainly at the draw-frame, have been described by Dakin, Foster and Locke.[31]

Study of yarn and sliver variability and its control in the mill have been greatly facilitated in recent years by the use of electronic equipment to measure and analyse the variation in linear density.

These researches have contributed much to shortened processing in which the use of higher drafts (that is, greater attenuation at one process) in conjunction with special drafting systems has permitted the elimination of one or more of the speed-frames. In the latest development[32] yarn is spun directly from draw-frame sliver using drafts up to 150, and in certain fields it seems likely that such machines will prove successful (Figure 5).

Another aspect of ring-spinning that has received considerable attention from research workers is the shape of and the tension in the rotating length of yarn (the 'balloon') that lies between the thread-guide and the traveller. Early work in this field was done by Balls,[33] whose suggestions for a spinning-frame combining some features of the mule with some of the ring-frame led many years later to the Gwaltney ring-frame in which it is possible to spin much larger bobbins of yarn. An important theoretical contribution was made by Grishin[34] working in Russia in 1934, but the information was not generally available until 1956.[35] Meanwhile, theoretical and experimental investigations have been undertaken by Mack, Gregory and Smart at the Shirley Institute[36, 37, 38] and by others. The resulting information has led to improved balloon control and facilitated the introduction of frames spinning much larger bobbins than hitherto. In fact, the limit to the size of the package is imposed, in this country at least, not by the yarn tension or the unmanageability of the balloon, but by the cost of power.

SIZING

With few exceptions, cotton warps cannot be woven without first being sized: an unsized warp would rapidly become a tangle of broken yarn. Briefly, the sizing process consists in impregnating the yarn with an aqueous adhesive paste and drying it, so that the yarn is better able to withstand the disruptive effects of the abrasion and oscillating stress to which it is subjected in the loom. By trial and error over a period of a hundred years workable sizing processes had been evolved, but before the Shirley Institute started investigating the matter about 1920, the scientific basis of the operation was very obscure. The task the Institute set itself was to find out not merely what steps are essential to produce

a weavable warp but how to produce one in which threads break as infrequently as possible during weaving.

The problem proved formidable for several reasons. First, if a warp is weavable at all then the occurrence of a warp break is a very rare event. A loom may be considered as a testing machine in which, say, 2,000 single threads are tested 10,000 times in an hour, yielding in a barely weavable warp, say, 5 breaks; that is, 1 break in 4,000,000 tests. Secondly, these breaks occur at random: an hour in which 6 breaks occur may be followed by one in which there are only 2. Thirdly, it is not possible to predict the breakage in the loom from laboratory tests; recourse must be had to large-scale weaving, carried out under proper statistical control.

Only an organization with resources as great as those of the Shirley Institute could have seen this colossal task to a conclusion. Pioneer work in the field was undertaken by Farrow and his co-workers,[39, 40, 41] particularly into the properties of starch films and starch pastes, starch being the most important adhesive for sizing cotton. The design of weaving experiments so as to reduce errors to a minimum was investigated by Main and Tippett[42] and by Bradbury and Hacking.[43]

As a result of this work it is now possible to specify for each kind of warp what ingredients should be present in the size mixing and in what proportions,

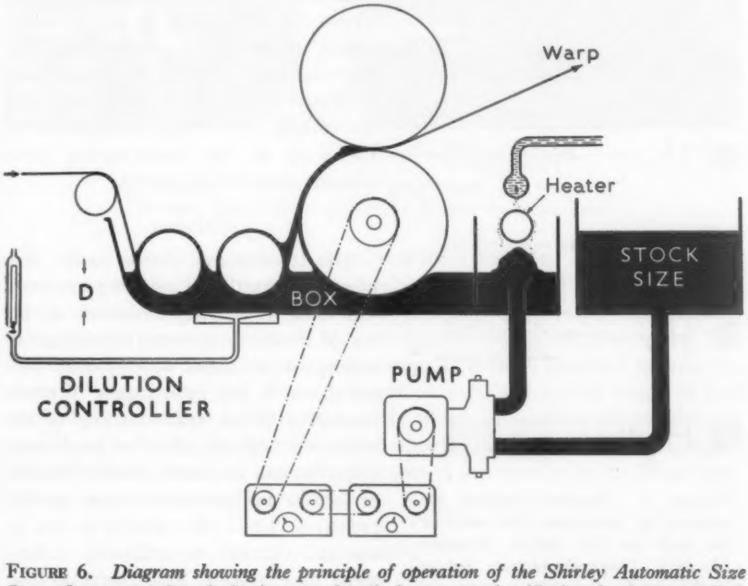

FIGURE 6. *Diagram showing the principle of operation of the Shirley Automatic Size Box. Concentrated stock size is metered to the box; water for diluting the size is supplied, heated and mixed with the size, whenever the dilution controller detects a fall in the depth D*

how much should be added, and how to add the desired amount with certainty, in order to achieve the minimum warp breakage rate. Much else was accomplished, particularly in the technique of sizing. Drying was brought under control by the use of an electrical moisture indicator[44] as early as 1933, based on the relation between moisture content and electrical resistance, and later research enabled the drying process to be considerably accelerated.[45]

The factors determining the amount of size taken up by the warp during sizing—viscosity and concentration of the size liquor, squeeze-roller pressure, and so on—proved to be so numerous and in many instances so uncontrollable, that in practice wide deviations from the target still occurred. This difficulty was overcome in a neat way by Jones and Shorter[46] with their invention of the Shirley Automatic Size Box, a device which enables a predetermined percentage weight of size to be applied to a warp irrespective of variations in the properties of the size liquor, or those of the yarn or of the machine characteristics. There are two essential requirements to achieve this: (1) the sizing ingredients, contained in a concentrated size liquor, must be fed to the machine at exactly the rate at which it is specified they should leave the machine on the warp (in contrast with what happens on a conventional machine where the size supply is uncontrolled, merely being fed to replace what has been used up); (2) the concentrated size is diluted with water in such a way that the volume of size liquor accessible to the warp in the impregnating bath remains constant (Figure 6).

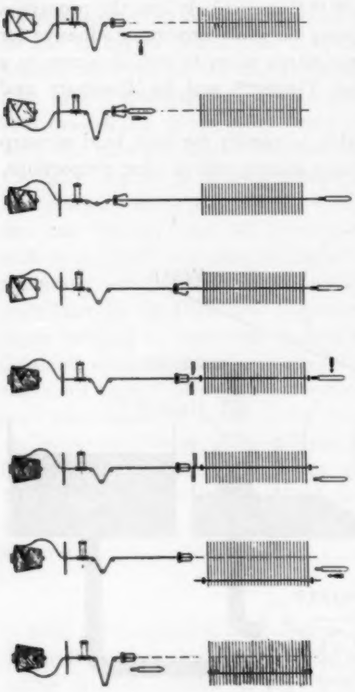

FIGURE 7. *Diagram showing the sequence of operations for inserting the weft on the Sulzer Weaving Machine. (Reproduced from* Sulzer Technical Review *No.* 1/1953, *by courtesy of Sulzer Brothers Ltd.)*

WEAVING

The conventional cotton loom, employing a shuttle for inserting the weft, was made completely automatic at the end of the last century and since then has undergone no major development. Research on it has been largely directed towards a better understanding of its behaviour and the effect of machinery imperfections on cloth quality. Shuttle projection in particular poses special problems, since the shuttle is not a machine element as ordinarily understood by engineers. Much work on this problem has been done at the Shirley

Institute and progress has been made in two main directions: in providing simple devices suitable for use in a weaving-shed, for controlling the speed, acceleration and retardation of the shuttle[47], and in placing the design of picking-cams on a rational basis.[48] The Shirley shuttle speedometer[49] is a good example of the kind of robust instrument necessary for use in the mill.

The advantages of drawing the weft from a large stationary package of yarn, instead of a small package contained in a shuttle, have long been recognized,[50] but attempts to apply the method in cotton weaving on a commercial scale had been unsuccessful until quite recently. Now the Sulzer Weaving Machine[51] appears to have established itself in certain fields. It employs a small dummy shuttle to grip the weft and carry it across the warp, the weft being then severed at the supply side and the cut ends tucked into each selvedge alongside the next length of weft. This loom, placed upon the United States market in 1952 and the European market some years later, has a long history of development going back to Rossmann's original conception in Germany in 1924. One fundamental problem with all shuttleless looms is the production of satisfactory selvedges, and it is the careful attention paid to this point, as much as any other feature, that has led to success where others had failed (Figure 7).

FIGURE 8. *A high-speed photograph of the weft emerging from the air-jet of the Maxbo shuttleless loom*

A more revolutionary type of shuttleless loom has been developed, first in Sweden by Pääbo[52] and later in Czechoslovakia by Svaty,[53] in which the weft is projected by means of an air-jet (Figure 8). These looms are still experimental, though there are one or two small industrial installations for special purposes. The significance of this development is that nothing tangible is projected between the sheets of warp except the necessary length of weft, and as this length of weft weighs only about one-tenthousandth of the weight of a normal shuttle, the way is open for achieving much higher loom speeds. Research on this and related methods of weft insertion is being undertaken in this country at the Manchester College of Science and Technology.

FINISHING

Broadly speaking, much of the research has been directed to removing the inadequacies that cotton has relative to some other fibre, and a large number of

chemical and mechanical treatments have been evolved. An early example is the crease-resist finish invented by Messrs. Tootal, Broadhurst Lee's Research Department[54] about 1927, the forerunner of the many resin treatments applied to-day.

As an example of a mechanical finishing treatment we may take compressive shrinkage, which has been widely adopted for such material as cotton shirting, where subsequent shrinkage is undesirable.

Other successful lines of research relate to process control. As examples may be cited the work of Clibbens and his collaborators on the effect of pH in the bleaching of cotton by hypochlorite[55,56] and the use of the fluidity of solutions of cotton in cuprammonium hydroxide as an indication of chemical degradation during bleaching or any other process. The latter test has proved of great value over a very wide field. The test was originally developed between 1911 and 1920 in connection with the manufacture of explosives from cellulose. In 1923 Farrow and Neale,[57] as a result of their investigations, suggested 'that bleachers and dyers would find in viscosity determinations a very sensitive means of controlling tendering by the chemical treatments they employ'. The method was further investigated and elaborated in great detail by Clibbens and his co-workers,[58,59] eventually being adopted as a standard test throughout the world.

CONCLUSION

As I approach the end of this lecture I become increasingly aware of the important work that I have found no time to mention, such as the operational research on the British cotton industry, with its special emphasis on activity sampling, carried out by Tippett[60] long before these terms were invented; the engineering approach to cloth structure pioneered by Peirce;[61,62] studies of the geometry and structure of cotton yarns by Schwarz[63,64] and Morton;[65] work on microbiological attack and its prevention; and all the work necessary to develop the many tests for measuring the physical properties of yarns and fabrics. I apologize to all those whose work I have been forced to exclude. Perhaps I should apologize still more to those whose work I have mentioned, because my necessarily perfunctory treatment completely fails to do justice to the thought and labour that these researches have entailed.

Acknowledgements

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REFERENCES

1. Commonwealth Economic Committee, *Industrial Fibres*, H.M.S.O., London, 1958, pp. 3, 68, 88, 210.
2. W. L. Balls, *Studies of Quality in Cotton*, Macmillan, London, 1928.
3. H. J. Denham, *Shirley Inst. Mem.*, 1924, Vol. III, 228-52.
4. G. S. Zaitzev, *Bull. App. Bot., Genet., and Plant Breeding*, 1924, Vol. 13, 132-4.
5. N. I. Vavilov, *Botanical-Geographic Principles of Selection*, United Publishing Houses of Federated Soviet Republics, Moscow and Leningrad, 1935.
6. J. B. Hutchinson, R. A. Silow, and S. G. Stephens, *The Evolution of Gossypium and the Differentiation of the Cultivated Cottons*, Oxford University Press, 1947.
7. R. L. Knight, *Cotton Breeding in the Sudan*, Empire Cotton Growing Corp. Res. Mem., 1955.
8. H. B. Brown and J. O. Ware, *Cotton*, McGraw-Hill Book Company, London, 1958, p. 133.

9. S. C. Harland, *The Genetics of Cotton*, Jonathan Cape, London, 1939.
10. Progress Reports from Experiment Stations, Republic of Sudan, Season 1957-8, Empire Cotton Growing Corporation, London, p. 21.
11. W. L. Balls, *The Yields of a Crop*, E. & F. N. Spon, London, 1953.
12. F. M. Eaton, 'Physiology of the Cotton Plant', *Ann. Rev. Plant Physiol*, Vol. 6, pp. 299-328.
13. H. Hibbert, *J. Ind. Eng. Chem.*, 1921, **13**, 256, 334.
14. W. N. Haworth, *The Constitution of Sugars*, Edward Arnold, London, 1929.
15. R. O. Herzog and W. Jancke, *Z. Physik*, 1920, **3**, 196.
16. O. L. Sponsler and W. H. Dore, *Colloid Symposium Monograph*, 1926, **4**, 174.
17. K. H. Meyer and H. Mark, *Ber. deut. chem. Ges.*, 1928, **61**, 593.
18. G. F. Davidson, *Journ. Text. Inst.*, 1936, **27**, p. P144.
19. D. A. Clibbens, *Journ. Text. Inst.*, 1954, **45**, p. P173–P193.
20. H. B. Brown and J. O. Ware, loc. cit., p. 398.
21. G. G. Clegg, *Shirley Inst. Mem.*, 1932, **11**, 1.
22. H. B. Brown and J. O. Ware, loc. cit., p. 404.
23. Ibid., p. 409.
24. E. Lord, *Shirley Inst. Mem.*, 1945, Vol. 19, p. 103.
25. E. H. Pressley, 'A Cotton Fiber Strength Tester', *Amer. Soc. Testing Mater. Bul.*, 1942, **118**, pp. 13–17.
26. F. T. Peirce, J. F. Kelly, and M. H. Coleman, *Journ. Text. Inst.*, 1955, **46**, p. T78.
27. W. L. B alls, *Studies of Quality in Cotton*, Macmillan, London, 1928, p. 122.
28. G. A. R. Foster, *Journ. Text. Inst.*, 1945, **36**, T229.
29. J. Gregory and A. Tyson, *Journ. Text. Inst.*, 1951, **42**, T147.
30. J. Gregory, *Journ. Text. Inst.*, 1951, **42**, T489.
31. G. Dakin, G. A. R. Foster and J. Locke, *Journ. Text. Inst.*, 1953, **44**, T544.
32. F. Charnley, *Textile Recorder*, 1959, **76**, p. 58.
33. W. L. Balls, *Studies of Quality in Cotton*, p. 103.
34. P. F. Grishin, Report of the Central Research Institute for the Textile Industry, Moscow, 1934.
35. P. F. Grishin, *Balloon Control*, T.M.M. (Research) Ltd., Helmshore, England, 1956.
36. C. Mack, *Journ. Text. Inst.*, 1953, **44**, T483.
37. C. Mack and E. J. L. Smart, *Journ. Text. Inst.*, 1954, **45**, T348.
38. J. Gregory, C. Mack and E. J. L. Smart, *Journ. Text. Inst.*, 1955, **46**, T606, 614.
39. F. D. Farrow and E. H. Jones, *Shirley Inst. Mem.*, 1926, **5**, 275.
40. S. M. Neale, *Shirley Inst. Mem.*, 1924, **3**, 207.
41. F. D. Farrow, G. M. Lowe and S. M. Neale, *Shirley Inst. Mem.*, 1927, **6**, 103.
42. V. R. Main and L. H. C. Tippett, *Shirley Inst. Mem.*, 1941–3, **18**, 109.
43. E. Bradbury and H. Hacking, *Journ. Text. Inst.*, 1949, **40**, P532.
44. J. W. S. Hearle and E. H. Jones, *Journ. Text. Inst.*, 1949, **40**, T311.
45. E. H. Jones, *Journ. Inst. Fuel*, 1957, **30**, 506.
46. E. H. Jones and S. A. Shorter, B.P. 654, 178.
47. I. H. Thomas and J. J. Vincent, *Shirley Inst. Mem.*, 1947, **21**, 277, 306.
48. C. M. Catlow and J. J. Vincent, *Shirley Inst. Mem.*, 1951, **25**, 101.
49. I. H. Thomas and J. J. Vincent, loc. cit. 321.
50. J. J. Vincent, 'The Advent of the Shuttleless Loom', *The Times Review of Industry*, July, 1953.
51. Sulzer Frères Soc. Anon., *Text. Merc.*, 1953, **128**, 634.
52. N. Karrlander, *Text. Merc.*, 1952, **127**, 601.
53. L. Taticek, *Tex.*, 1955, **14**, 1678.
54. Tootal Broadhurst Lee Co. Ltd., R. P. Foulds, J. T. Marsh, F. C. Wood *et al.*, *B.P.* 291, 473 and *B.P.* 291, 474.
55. C. Birtwell, D. A. Clibbens and B. P. Ridge, *Shirley Inst. Mem.*, 1924, **3**, 321.
56. D. A. Clibbens and B. P. Ridge, *Shirley Inst. Mem.*, 1927, **6**, 1.
57. F. D. Farrow and S. M. Neale, *Shirley Inst. Mem.*, 1923, **3**, 67.
58. D. A. Clibbens and A. Geake, *Shirley Inst. Mem.*, 1927, **6**, 117.
59. D. A. Clibbens and A. H. Little, *Shirley Inst. Mem.*, 1936, **15**, 26.
60. L. H. C. Tippett, *Operational Research Quarterly*, **1**, No. 2, June 1950.
61. F. T. Peirce, *Shirley Inst. Mem.*, 1930, **9**, 83.
62. F. T. Peirce, *Text. Res. Journ.*, 1947, **17**, 123.
63. E. Schwarz, *Journ. Text. Inst.*, 1933, **24**, T105.
64. E. Schwarz, *Text. Res. Journ.*, 1951, **21**, T125.
65. W. E. Morton, *Text. Res. Journ.*, 1956, **26**, 325.

III. RESEARCH IN MAN-MADE FIBRES

by

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Man-made fibres, of one kind or another, have now been with us for a period of about 70 years, having made their first appearance well before the close of the last century in forms long since obsolete. The middle '20s of the present century thus divide this period into two roughly equal halves, but they also mark, with a fair degree of precision, a turning point in the whole story, because it was then that there emerged for the first time a simple theoretical picture of the molecular architecture of polymers that was to exercise a profound influence on the course of subsequent events. Up to that point, the part played by research lay very largely in the capitalization of empirical ideas and observations: thereafter it was to lie more and more in the capitalization of theoretical knowledge and understanding. The distinction is not sharp but it is sharp enough. It is always easier to work in the light than in the dark; you can see what you are doing and get on much faster. During the first of our two periods the light had been poor, but in the middle '20s it suddenly improved and soon became quite bright. We might continue the metaphor by saying that this led to better working conditions which in turn attracted more workers. New possibilities were seen, pursued and exploited, and before long new fibres of a kind hitherto undreamt of made their appearance on the scene. These were the fibres of purely synthetic origin.

As a prelude to our discussion of research in this domain let us begin by taking a brief look at the situation as it existed in the year 1926.

The issue of *The Times* of 9th March of that year carried the following announcement: '*The Times* presents to its readers to-day, free of charge, a fully illustrated Artificial Silk number which describes the nature and possibilities of this interesting new textile about which so little is as yet generally known.'

In that year the world output of this 'interesting new textile' amounted to some 200 million pounds, of which the British share was about 13 per cent, and that of the United States about 30 per cent. Already production was dispersed among a number of countries and had given rise to much lively international trading. Italy, Holland and Belgium, for example, between them contributed rather more than 30 per cent of the global output but consumed a mere 8 per cent of this. However, as the late Mr. Samuel Courtauld remarked at the time, 'England already consumes about twice as much artificial silk per head as any other country, not excluding the United States, and our home market is nearer to saturation than any other. This shows that development was earlier here but it also means that less remains to be done.'

In the light of more recent happenings this pronouncement may read a little strangely to-day. But it was, no doubt, an authoritative view of the situation

as it appeared at the time and could not have been substantially changed except by anticipating the course and the outcome of future research, and for this there was no real justification. Following the basic inventive steps taken before 1900, 30 years of intensive effort had already gone into the development of artificial silk and—to use modern jargon—an extensive and elaborate 'know-how' had been established. The product doubtless appeared capable of marginal improvement, but considered by and large it had an undeniable air of finality about it. This indeed was a great tribute to the work of those who had devoted their energies to laying the technical foundations of the industry and likewise to the success of the empirical methods which they had had necessarily to adopt. Let it also be added that throughout most of this period these pioneers received little or no help from their brethren in the academic world who had consistently ignored a growing accumulation of intriguing experimental observations. But now in the middle '20s a change set in and this long-deferred help was at last forthcoming.

In essence, this took the form of a few quite simple ideas which embraced not only cellulose, the substance from which all man-made fibres had, up to that time, been derived, but polymers and polymerization phenomena as a whole. The truly fundamental theories of macromolecular chemistry are now so well known as to require no particular account in this lecture: they have become incorporated in the general body of scientific knowledge and are now taken for granted.

I shall now attempt to show how an area of empirical investigation, undertaken during the later years of our first period and one which had already proved of much practical value, especially in connection with the bleaching of cotton, was carried forward into the second period and there, under the influence of the theories to which I have referred, became transformed into one of the great directing principles underlying the production of all man-made fibres.

The empirical investigation in question had established correlations between the tenacity of cellulosic fibres and their viscosity in cuprammonium solution. Shortly afterwards the viscosity of polymer solutions in general began to attract a wider interest. Let me now quote from a comparatively recent lecture by Dr. D. A. Clibbens,[2] who himself has made such outstanding contributions to this subject.

'Staudinger', says Clibbens, 'was the first to put forward the hypothesis that viscosity is a function of the length of the polymer chain and that changes in viscosity are related to changes in its chain length or degree of polymerization. When Staudinger's postulate was considered in the light of our own empirical discovery of a close relation between viscosity and tensile strength, the hypothesis immediately led to the conclusion that tensile strength is also a function of the length of the polymer chain.' Clibbens then goes on to say: 'The difference in the quantitative relation between viscosity and strength for the native and regenerated cellulose fibres showed the additional importance of the arrangement of the macromolecules in the fibre—an arrangement which is altered when molecules are shuffled and re-assembled by dissolution and regeneration from a solution.'

The second part of this quotation, concerned with the different relationships exhibited by native and regenerated cellulose fibres, is of special significance. If the viscosity of native cellulose were to be reduced to that of the regenerated form by some process of chemical attack, practically the whole of its original tenacity would be lost: yet the regenerated fibres themselves were comparatively strong. The idea that strength was a function of degree of polymerization or molecular weight was straightforward and not difficult to grasp: that it was also a function of molecular arrangement was a far more subtle but equally far-reaching conception. Neither of these ideas is confined to the case of cellulosic fibres; they are both applicable to all fibres irrespective of origin or chemical composition.

I have dealt briefly, and necessarily incompletely, with the origin of these two ideas because between them they have provided a kind of framework within which a high proportion of all research on man-made fibres has since been conducted. They pose by implication the fundamental question of the relation between the physical properties of these fibres on which much of their value ultimately depends and, on the one hand, the molecular weight of the polymers from which they are derived, and, on the other hand, the spatial arrangement of the chain-like molecules within the fibres themselves. There are many facets to this question and some of the problems to which it gives rise are still far from solved.

Measurement of viscosity in a solvent remains the most important method for the assessment and control of molecular weight, but the mere fact that we are always confronted with a molecular weight distribution itself raises a host of problems, more especially concerned with the influence on fibre properties of the presence of varying proportions of molecules far below the average size. As a result, much patient and exacting work has been undertaken on the fractionation of cellulose, cellulose acetate and the polymers from which the modern synthetic fibres are derived—work which is perhaps only just beginning to show any real reward. But in any case, the actual control of molecular weight distribution is difficult to achieve in practice and we have therefore frequently to accept some particular distribution if only because we cannot change it.

When, however, we come to consider the question of the spatial arrangement of molecules within the fibre we meet with a very different situation which over the years we have been learning to control with ever-increasing effectiveness. The process on which we rely and which, in one way or another, we adapt to every circumstance, is the process of stretching.

When fibres emerge from the holes of a spinneret there is some transient point covering the first few micro-seconds of their existence—a point which we might roughly describe as representing a state somewhere between liquefaction and solidity—at which effective stretching is possible. This has long been realized, but full recognition of what can be accomplished in this way has come only rather slowly. With viscose rayon this led first to great improvements in the strength and certain other qualities of the yarn which about 10 years ago enabled this fibre almost completely to replace cotton in the manufacture of tyre cords. Within the past few years these improvements have continued and this gives

point to a statement made by A. H. Wilson in 1953 to the effect that 'the technology of viscose manufacture has once again become fluid'.[3] The following quotation from a recent publication will serve as an illustration of this forward movement. 'Perhaps the most important factor leading to development of the improved technology is the recognition that certain chemicals added to viscose serve to stabilize xanthate decomposition, thereby prolonging the period when effective stretching may be applied.'[4] What is in fact achieved is a particular degree of orientation of the chain molecules not merely near the surface

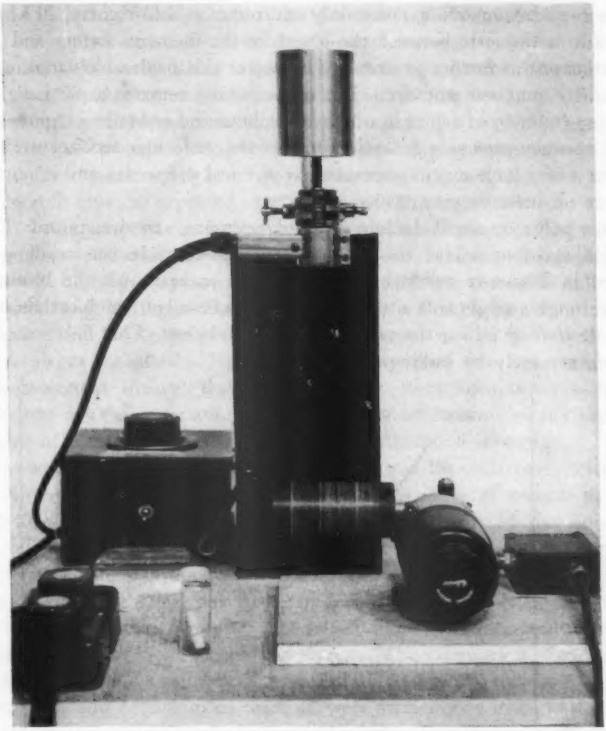


FIGURE 1. *Apparatus for spinning and drawing 'Terylene' fibre*

but throughout the fibre, and it is to this that the improvement in properties must be ascribed. It is perhaps unnecessary to say that such improvement entails an increase in the cost of production of a fibre which owes much of its success in the past to its relatively low price. The extent to which this advanced technology will be adopted throughout the industry as a whole therefore remains an open question.

With fibres such as nylon and 'Terylene' a new set of circumstances arises. These fibres are produced, not by the extrusion of polymer solutions but of polymer in the molten state, and solidification results from the cooling of the melt. Even so, there exists that critical point at which stretching may be applied by drawing off the fibres at a higher rate than that at which they are extruded, and in this way we can control the degree of molecular orientation. With nylon, crystallites make their appearance at this stage, but with 'Terylene', the transition point is higher and the filaments are devoid of actual crystallinity. However, in both cases the filaments are susceptible to further stretching and this constitutes a separate operation commonly referred to as cold-drawing. The so-called draw ratio is the ratio between the length of the filaments before and after the application of this further process and is subject to considerable variation according to the conditions employed. But cold-drawing remains a particular case of stretching resulting in a fibre in which amorphous and crystalline regions co-exist. This is now accepted as a general feature of the molecular architecture of fibres which to a very large extent governs their physical properties and is not without influence on their chemical behaviour.

At this point an actual demonstration of spinning and drawing of 'Terylene' fibre will serve to relieve the monotony of the text. In the small apparatus depicted in Figure 1 a block of polymer is melted and the molten mass forced through a single hole at the base to form a filament which is then collected at any desired speed on the revolving cylinder below. This fibre can then be cold-drawn merely by pulling it.

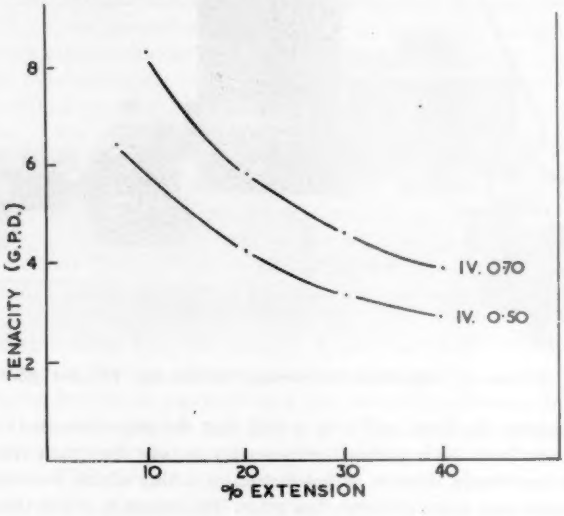


FIGURE 2. *Graph showing tenacity and extensibility of 'Terylene' fibres*

Of the innumerable illustrations which might be given in support of the broad theme we have been discussing—that of the dependence of the physical properties of a fibre on the average size of its chain molecules and their spatial arrangement—I have time to cite only one. In Figure 2 the tenacity and extensibility of 'Terylene' fibres derived from two polymers which differ considerably in average molecular weight as shown by differences in their intrinsic viscosities, are plotted one against the other. The points on the curve for each polymer correspond to particular draw ratios, so that with respect to properties measured it is seen quite clearly how these depend both on average molecular weight and the actual arrangement of the molecules as determined by stretching.

Before leaving this aspect of the subject, mention may be made of an additional circumstance which seems likely to keep research in this direction alive for a long time to come. The highest tenacities so far reached for any fibre still fall far short of the tenacities calculated from the forces required to rupture the covalent bonds of the main chains. It may well be that these higher tenacities are beyond attainment for reasons which are not yet entirely clear, but until this is finally settled research must be expected to continue with the target in mind.

All this vast amount of research undertaken against a background of molecular weight and molecular arrangement owes so much to macromolecular theory that it would be easy to ignore the fact that, in practice, the empirical element still persists quite strongly. But when we turn to a consideration of the circumstances which led to the modern synthetic fibres we shall find the empirical element vanishes completely. Here the basic discoveries were not merely aided by macromolecular theory; they could scarcely have been made without it. This is not to say that they were unattended by good fortune, in the sense that an element of unexpectedness is the essence of nearly all invention.

The avowed object of the work of Staudinger and his collaborators had been to seek an understanding of the molecular architecture of natural polymers, among which cellulose was but one. But Staudinger believed that this might be achieved more readily by first making a study of some less complex polymeric substances which could be obtained by actual synthesis from monomers. Beginning with the polyoxymethanes derived from formaldehyde, he later extended his ideas to various polymers formed by the self-addition of unsaturated compounds such, for example, as vinyl acetate and styrene. The existence of such polymers was already known and a number of them had in fact been known for a long time. The properties and behaviour of them all were soon shown to be in accordance with the general macromolecular theory. If by then this theory was thought to be in need of further confirmation—and there were, of course, those who felt this to be the case—all doubts were finally set at rest by the work of Carothers which he began in 1928, that is to say very early in our second period, and which during the course of the next few years was to lead him directly to the discovery of nylon. Not that Carothers himself was much concerned with obtaining further proof of the theory: from the first he was content to accept it and he set out to pursue its consequences in a particular direction which up to that point had largely escaped notice. In his own words his aim was 'to synthesize giant

molecules by strictly rational methods',[5] and this aim could not even have been conceived except in terms of macromolecular theory. We might therefore go on to assert that without this theory the modern synthetic fibres would almost certainly have remained unknown to this day. As we have already seen, the theory itself dates from the year of Samuel Courtauld's pronouncement, who at that time probably knew nothing whatever about it and who, even if he did, could scarcely have been expected to foresee its consequences.

The practical achievement of Carothers was to establish a new method for the synthesis of linear high polymers based on intermolecular reactions of bifunctional compounds and thus ultimately on the ordinary condensation reactions of classical organic chemistry. Despite the power and the generality of this method only two classes of condensation polymers have so far been found of value as a source of fibres, although many have at various times been examined from this point of view. These two classes are the aliphatic polyamides which are due to Carothers himself, and the aromatic polyesters, which Dr. Dickson and I first described in 1941.[6]

Practical considerations largely restrict the choice. A capacity to yield oriented fibres was first demonstrated by Carothers in the case of certain aliphatic polyesters, but these were of no value if only because aliphatic polyesters of this class have low melting points.

Polymeric ethylene adipate is a typical aliphatic polyester. It can be obtained in a condition of high molecular weight by heating together ethylene glycol and adipic acid and removing the water formed from the sphere of the reaction. It is built up from the recurring unit

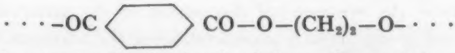
$$\cdots\cdot -OC(CH_2)_4-CO-O-(CH_2)_2-O \cdots\cdot$$

When molten it is extremely viscous and the melt can be extruded through a spinneret to form filaments which can then be cold drawn to yield oriented micro-crystalline fibres of considerable strength and pliability. Unfortunately these fibres melt at a temperature of a little above 50°C., and no member of this series of aliphatic polyesters has a melting point much above 100°C.

It was this circumstance that led Carothers to turn his attention to the analogous polyamides which he found to have a similar capacity to yield oriented fibres but which also possessed a very much higher range of melting points—for the most part well above 200°C. This was a singularly happy discovery, and naturally one of the greatest practical importance, but in a sense a mere incident in his long series of researches. Comparing the polyamides with the polyesters, Carothers, was content to say 'The difference lies in the direction required by the much higher molecular cohesions of amides as compared with esters', and to leave it at that.

The discovery of 'Terylene' a few years later (1941) was to reopen the whole question of the melting point of high polymers and to unleash a flood of theoretical speculation and ideas on this and on other questions besides.

The structural unit in 'Terylene' is

(polyethylene terephthalate) 

and if this is compared with the structural unit of polyethylene adipate, it is at once seen that the difference lies in the replacement of the flexible chain of 4 methylene groups in the latter by the very rigid aromatic nucleus. The effect of this on melting point proved to be dramatic—an increase of over 200°C. Curiously enough, the melting point of 'Terylene' turned out to be within a few degrees of that of nylon 66 derived from adipic acid and hexamethylene diamine where the structural unit is

$$\cdots\ \text{—OC(CH}_2)_4\text{—CO—NH(CH}_2)_6\text{NH—}\ \cdots$$

However, the mere inclusion of the aromatic nucleus in the repeating segments of the chain is not in itself sufficient to yield polymers of high melting point or indeed polymers capable of yielding oriented fibres. These properties result

SYNTHETIC FIBRES

PRIMARY INVENTION (NUCLEI)		DEVELOPMENT (GROWTH)
	1925	
(Modern High Polymer Theory Rapidly Evolving)		
(Publication of Carothers' first paper on C-Polymerisation.)	1930	
First oriented fibres produced from C-Polymers First synthetic polyamide described (leading to nylon) First oriented fibres produced from polyamide of 9-amino-nononic acid	1935	Development work begun on polyamides (nylon)
First oriented fibres produced from hexamethylene adipamide (afterward nylon 66) Discovery of reversible reaction between caprolactam and polyamide (leading to Perlon etc.)	1940	Nylon in commercial production
Solvents found for polyacrylonitrile and fibres made from the solutions (leading to Acrylics) Polyethylene terephthalate first synthesised and oriented fibres produced therefrom (leading to "Terylene" etc.)		Development work begun on acrylic fibres Development work begun on polyester fibres
	1945	
[No new fibres invented between 1941 and 1955]		
	1950	Acrylic fibres in commercial production
Discovery of isotactic polymers; oriented fibres made from i-polypropylene, etc. (leading ?)	1955	Polyester fibres in commercial production.

FIGURE 3. *Chronological table showing the invention and development of synthetic fibres*

from the symmetrical disposition of the carboxyl groups in the para position, and it was from a consideration of the relations between molecular symmetry, crystallinity, and fibre-forming capacity that 'Terylene' itself came to be discovered. The corresponding polyesters derived from o-phthalic acid were already known in 1941 and these were all low melting solids which could not be induced to crystallize or to yield fibres.

In addition to the aliphatic polyamides and the aromatic polyesters there is a third class of synthetic fibres which has achieved great importance—the so-called acrylic fibres. These stem from polyacrylonitrile or copolymers of acrylonitrile and other vinyl monomers. Polyacrylonitrile had long been known and was among the few addition polymers possessing a high melting point. But since melting is accompanied by decomposition, the technique of melt spinning was out of the question. Everything therefore depended in the first instance on whether polyacrylonitrile (or its copolymers) could be brought into solution. This was eventually achieved by means of a few unusual solvents, dimethyl formamide being among the first of these to be found. Once solution had been accomplished the way lay open and acrylic fibres are now produced both by dry and wet spinning.

In the table (Figure 3) I have attempted to portray in some sort of chronological sequence the way in which these three classes of synthetic fibres emerged upon the scene. The foundations for them all were laid within a comparatively short space of time—certainly not more than 10 years—and hard on the heels of the early development of macromolecular theory in the middle '20s. The initial capitalization of this theory in regard to fibres was therefore remarkably rapid, and it is particularly significant that after 1941 a long period was to elapse during which no new classes of fibres attained commercial importance. It was not, in fact, until 1955 that the researches of Ziegler and Natta resulted in the discovery of means by which regularity in the disposition of lateral substituents in linear polymers could be achieved, thus making available a new class of fibres, such as those derived from isotactic polypropylene, which are now beginning to attract interest.

REFERENCES

1. *The Times*, Artificial Silk Number, 9th March, 1926.
2. D. A. Clibbens (Mather Lecture), *J. Text. Inst.*, 1954, **45**, 173.
3. A. H. Wilson, *J. Text. Inst.*, 1953, **44**, 130.
4. D. K. Smith, *Text. Res. J.*, 1959, **29**, 32.
5. W. H. Carothers, *Collected Papers*. Interscience Pub. Inc., 1940.
6. J. R. Whinfield, *Nature*, 1946, **158**, 930.

GENERAL NOTES

THE EDINBURGH FESTIVAL

Official prefaces to souvenir programmes customarily contain platitudes. But the Lord Provost of Edinburgh, in reminding us that the city's Festival of the Arts 'had its origin in an earnest desire to promote the happiness and universality of mankind', touches the heart of the matter. No other city in Britain or the Commonwealth has done so much as this Northern capital since the War to extend the understanding of a variety of cultural heritages through an international Festival of music, drama, ballet, the arts of painting, sculpture, and the serious cinema—

Lamentations over Christ, *by a Czech Master. Wood,* c. 1500. (*From the Exhibition of Czech Art at Edinburgh*)

inevitably running into financial and occasionally political difficulties, but still steadfast in its high purpose. Indeed, such disappointments as the unexpected withdrawal of an orchestra, or the inadequacy of a Continental exhibition for political reasons, are no more than a reminder that artistic enterprise, however elaborately planned, is as incalculable as the skies—which turned out, in fact, to be in smiling mood this autumn in Edinburgh.

In the visual arts, it must frankly be said that the Festival's principal offering of Czech art over the past six hundred years, at the Scottish Academy, left much to be desired in its selection and contained only a meagre representation of the medieval painting and sculpture which constitute the glory of Czech art. Those who saw the exhibition of this early art at the Musée des Arts Décoratifs in Paris two years ago could easily understand how its beauties were at one time famous throughout Europe. In the Edinburgh exhibition, however, only two limewood Madonnas were allowed to stand for the tender mastery of Czech fifteenth-century carving, and a whole century after 1530 was skipped on the pretext that the active artists at that time were foreign settlers. Thus the collection passed straightway from the Gothic period to the generally sombre and undemonstrative Baroque, and thence to the nineteenth and twentieth century artists following, with few individual variations, in the wake of the main European styles of the day.

Even so, one was grateful for the sight of a few examples of Czech medieval art of a tender and lyrical character, fusing northern and southern Gothic traditions. One of the most endearing of these (all drawn from Prague galleries) represents St. Elizabeth feeding a beggar, by the master Theodorik. The peculiar graciousness

of the mid fourteenth-century painting could be seen also in the so-called *Veveří Madonna*, very subtle in the arrangement of delicate fingers that find an extension and echo in the agitation of transparent drapery about the child's limbs. Besides the main Czech collection in the central rooms, there was a case of fine Bohemian glass in the sculpture hall, an arrangement which led one to cast an eye round the Scottish Academy's largely displaced show of works by members who submit to much self-denial at this season. When Edinburgh's projected museum of modern art becomes a reality, there should be more accommodation for visiting Festival exhibitions.

In general, the Academy's sculpture confirmed established reputations with works by such refined modellers as Eric Schilsky and C. d'O. Pilkington Jackson; and as characteristic were the architectural designs from Basil Spence, and J. L. Gleave, whose massive cruciform memorial to Columbus, long familiar in initial stages, has yet to shed its great cross of light upon the night sky. The exotic richness of John Maxwell's colour and the sensitive romanticism of Anne Redpath once again found company with good things from the President, William MacTaggart, and from a conspicuous Associate, Joan Eardley, both of whom were also holding shows in neighbouring galleries. Indeed, Mr. MacTaggart's exhibition of recent paintings at the Scottish Gallery was one of the Festival's happier offerings. The most jubilant of expressionists, rejoicing in the luxuriance of a bowl of fruit in a casement opening on to a starry night, he invests the Edinburgh scene with an encrusted richness and fieriness of colour that proceeds without any sense of forcing from his strange intensity of vision.

Music and drama are traditionally the main draws of the Festival, but the crowds of foreign visitors, with many Americans in evidence, who have been swarming about Princes Street and the Lothian Road, did not ignore the art exhibitions even on the fringe. In fact, two of the principal supporting collections comprised works of exceptional quality. The full extent of the late Sir William Burrell's collection bequeathed to Glasgow is known perhaps only to a few experts, for such material as has been taken out of packing cases has been exhibited piecemeal. It came therefore as a revelation to Edinburgh when the sumptuous Gothic tapestries and French stained glass were arranged, with other medieval objects of art from the shipping magnate's bequest, in the Royal Scottish Museum. All the Gothic elaboration of marvellous detail seems, indeed, epitomized in that Touraine tapestry showing Charity on her elephant slaying Envy, against a field of 'mille fleurs' pattern; and all the sly humour and wonder of the age in that caravan of camels (one beast snapping at another) as they rear and sway in Vasco da Gama's expedition to the Indies across the tawny breadth of a Tournai tapestry. Indeed, medievalism was the keynote of the visual arts this autumn. And the historic sense was stirred again at an assemblage of Scottish decorative arts of the Renaissance at the Portrait Gallery, a compact arrangement notably of carved woodwork interspersed with portraits as arresting as a head of ghostly pallor of James VI as a child.

In London, meantime, the late summer and early autumn have brought nothing whatever to the galleries to approach the magnificence of the Romantic Exhibition. But it may not seem altogether incongrous to mention in the same breadth one of the most popular—as it is also the most innocently romantic—of London's annual exhibitions, due to close on 30th September. This year, the *Sunday Pictorial* rings the changes in its annual exhibition of children's art with a 'basic form' display devised by Victor Pasmore, some lively and amusing grotesques in *papier mâché* introduced by Eduardo Paolozzi, and a section of children's neatest calligraphy, mainly in the italic system, which wins the approval of Alfred Fairbank, that traditional scribe. But it is the young painters, from dream-days to adolescence, who take exuberant command at the Royal Institute Galleries in Piccadilly.

NEVILE WALLIS

'COMMUNICATION IN THE MODERN WORLD'

The British Association for the Advancement of Science, in association with Granada TV Network, has arranged a series of three Inaugural Granada Lectures on the theme of 'Communications in the Modern World'. The lectures will be delivered in the Guildhall, London, E.C.4, as follows: Tuesday, 13th October: Sir Edward Appleton; Monday, 19th October: Dr. Edward R. Murrow; Tuesday, 27th October, Sir Eric Ashby. In each case the lecture will begin at 8.30 p.m.

By courtesy of the organizers, a limited number of tickets for the lectures are being reserved for Fellows of this Society, and those who wish to attend any or all of them are invited to apply without delay to the Secretary of the British Association, 18 Adam Street, London, W.C.2.

FREE TRADE ASSOCIATION OF THE 'SEVEN'

In May of this year, after the failure of negotiations for a European Free Trade Area which would embrace other countries besides those Six already associated together by the Treaty of Rome, Sweden put forward proposals for the formation of a Free Trade Association among the 'Outer Seven'—herself, Norway and Denmark, Austria, Switzerland, Portugal and the United Kingdom. This Swedish idea met with an immediate response, and progress has since been so rapid that little has yet been published about it. The White Paper issued by Her Majesty's Government at the end of July gave the text of the Draft Plan and will provide the basis for the Convention now being drafted, but probably only a few people have much knowledge either of the scope of the new Association or of the circumstances which led up to it.

A Chamber of Commerce booklet has therefore been prepared, under the title *The Seven*, to provide business men with a simple guide. The booklet outlines the background of the earlier, abortive, attempt to form a European Free Trade Area and the negotiations amongst the 'Seven'; summarizes briefly the Stockholm Draft Plan; and gives some statistics on the trade of the proposed Free Trade Association. Copies of *The Seven* (price 2*s* 6*d*) can be obtained through any Chamber of Commerce affiliated to the Association of British Chambers of Commerce.

CONFERENCE ON INDUSTRIAL ARCHÆOLOGY

The Council for British Archæology has recently formed a research committee for the archæology of the industrial revolution. The committee includes archæologists, economic historians, geologists, architects, technologists, and others interested in surviving remains of the seventeenth, eighteenth and nineteenth centuries. In order to focus attention on the possibilities and immediate requirements of research on this subject, a conference is being held on Saturday, 12th December, at the London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), W.C.1. Amongst the papers to be read at the meeting (which will include opportunities for discussion) are 'The Stamford Canal: a seventeenth-century navigation', by J. M. Palmer and M. Berrill, 'The structure of early cotton mills', by Professor A. W. Skempton, and 'The Ordnance Survey in relation to the recording of industrial archæology', by C. W. Phillips. A conference fee of 5*s* will be charged. Applications to attend should be sent to the Assistant Secretary, Council for British Archæology (10 Bolton Gardens, London, S.W.5), who will also supply further particulars of the programme.

EXHIBITIONS OF SWISS INDUSTRIAL ARCHITECTURE AND DESIGN

The 'Swiss Fortnight' to be held in this country from 5th to 17th October will comprise an extensive programme of events designed to present aspects of Swiss life, culture and achievements to the British public. Two London exhibitions which are part of this Festival may be singled out here as being likely to prove of special interest to Fellows.

At 66 Portland Place, from 6th to 17th October, the R.I.B.A. is presenting an exhibition of Swiss industrial architecture. Switzerland is a much more highly industrialized country than is generally realized, but by dint of careful siting and planning, ugly industrial centres have been avoided. The exhibition, which has been prepared by the Federation of Swiss Architects, will contain plans, models and sculpture, and will show developments in design and layout achieved by Swiss architects with the co-operation of factory owners. There is no charge for admission to the exhibition, which is open on Mondays to Fridays from 10 a.m. until 7 p.m., and on Saturdays from 10 a.m. until 5 p.m.

An exhibition of Swiss posters and industrial design, including textiles, furniture, glass, pottery, kitchen and sports equipment, will be on show at the Tea Centre, Lower Regent Street, from 7th to 17th October (Mondays to Fridays, 10.30 a.m. to 6.30 p.m.; Saturdays, 10.30 a.m. to 1 p.m.). Admission here is also free.

ROYAL COMMONWEALTH SOCIETY MEETINGS

By courtesy of the Royal Commonwealth Society, a limited number of tickets for its lunch-time and evening meetings in the coming months are being made available to Fellows of this Society. A list of the meetings arranged during October is given below, and those Fellows who would like to attend any or all of them are asked to apply to the Secretary as soon as they can. (In future issues of the *Journal* the details of these meetings at the Royal Commonwealth Society will be given under 'Some Activities of Other Societies and Organizations'.)

Lunch-time Meetings (1.15 *p.m.*)

1st October. *African Growing Pains—Second Phase*, by Professor W. M. Macmillan.
8th October. *Prospects for Cyprus*, by Miss Penelope Tremayne.
15th October. *Pakistan To-day*, by the High Commissioner for Pakistan.
22nd October. The Earl de la Warr will speak on his visit to Ceylon, Australia and New Zealand.
29th October. *Investment in the Commonwealth*, by the Viscount Chandos.

Evening Meeting (8 *p.m.*)

6th October. *Is the Author Obsolete?* by John Connell.

ERRATUM

In the note on the A. E. Housman Centenary Exhibition published in the September issue of the *Journal* (p. 719), it was stated that Housman was Professor of Poetry at University College, London, from 1892 to 1911. In truth, he was Professor of *Latin* at the College during this period. This error is regretted.

STUDIES IN THE SOCIETY'S ARCHIVES VIII

THOMAS WILKINS, THE SOCIETY'S PRINTER, AND LORD GEORGE GORDON

The celebrated 'No-Popery' Riots which were sparked off by Lord George Gordon in June, 1780, do not appear to have troubled the Society of Arts.[1] Seven years later, however, the Society was to see its printer brought to trial in company with the agitator and, in consequence, to have Volume VI of its *Transactions* printed from Newgate Prison. The Society had begun to publish annual volumes of printed *Transactions* in 1783.[2] The printer of the volumes for 1784, 1786, 1787 and 1788 was Thomas Wilkins, master printer and a freeman of the Stationers' Company,[3] who at some time in 1786, if not before, had made the acquaintance of Lord George Gordon.[4] After a remarkable acquittal from the charge of high treason which had been made against him after the Riots, Gordon had engaged in a variety of political intrigues and public quarrels.[5] His dispute with the Archbishop of Canterbury caused him to publish two pamphlets in June, 1786. They were: *A Letter to his Grace the Lord Archbishop of Canterbury occasioned by the Excommunication of the*

Right Honourable Lord George Gordon for non-conformity to the Mandates of the Spiritual Court,[6] and *An Appeal from Scotland; in which the Spiritual Court of the Church of England, is demonstrated to be opposite to the British Constitution and a Part and Pillar of Popery.*[7] Both these pamphlets were printed by Thomas Wilkins. In December of the same year, Wilkins printed a third pamphlet for Lord George. It was *The Prisoners' Petition to the Right Honourable Lord George Gordon, to preserve their Lives and Liberties and prevent their Banishment to Botany Bay,*[8] which although to modern eyes a justifiable enough attack 'on the bloody hue of the felony laws',[9] was held by the Attorney-General to be a libel on the Judges and the administration of the laws in England.

Wilkins and Gordon were not brought to trial until June, 1787, and in the meantime the contract for printing Volume V of the Society's *Transactions* had gone to Wilkins, an objection from one of the members to his association with Gordon being overruled.[10] Gordon had also been served with a writ for a libel on the Queen of France, which he had published in 1786, and, as no action had been taken against its printer, he assured Wilkins that he need have no fears and, according to Wilkins's subsequent testimony, he promised to indemnify him whatever happened.[11] Gordon was unable to secure the services of the counsel who had defended him at his previous tiial, so he decided to conduct the case himself and ignored Wilkins's plea that counsel should be retained.[12] His handling of the case was both eccentric and irregular. *The Prisoners' Petition* was found to be libellous and Gordon was proved to have published it. Wilkins's defence was possibly even worse than Gordon's. He claimed that he had received the pamphlet in detached pieces and had not read it through until 'it was absolutely printed'; that he could see 'no evil tendency at all in it myself'; and that Lord George Gordon 'promised to indemnify me whatever evil might accrue from it; and that is all I can say in my defence'.[13] The Attorney-General referred to him as 'the present unfortunate defendant'[14] and, according to Wilkins, looked upon him with pity,[15] but this was of no avail in softening the indignation of the judge at the mention of an indemnity:

> It is fit you should know that no man ought to trust to an indemnity; and in order to remove all abuses of that Kind, the Court will inflict such a punishment upon you, against which no man can indemnify, namely the punishment of your person . . . The sentence of this court is that you be imprisoned for the space of two years, in his Majesty's Gaol of Newgate.[16]

Wilkins's sentence was passed on 27th June, 1787, and he was, accordingly, a prisoner in Newgate when the Society began to consider publishing Volume VI of its *Transactions,* early in 1788.[17] It appears that objections were again raised to the employment of Wilkins, although, as before, these are not recorded in the Minutes. On 5th February, 1788, he wrote two letters of extenuation to Valentine Green, a Chairman of the Society's Committee of Correspondence and Papers, one of which is appended below. The letters were read to the Committee on the same day that it met to consider a reference from the Society empowering it 'to apply to not less than Six Printers to enable them to recommend to the Society a proper person to prınt the Sixth Volume of the Society's Transactions'.[18] The Committee included Wilkins in its list of six names but, on 12th February, it found that the estimate submitted by John Walter was the cheapest and 'resolved to recommend him to the Society to print the Sixth Volume of their Transactions'.[19] On the next day, 13th February, a meeting of the Society was held at which a letter from Wilkins was read containing favourable terms for the supply of paper, and the Committee's recommendation was referred back for further consideration.[20] The Committee met on the 19th and heard a further letter from the prisoner, reducing the terms of his estimate, which it accordingly accepted.[21]

It is doubtful if, as Wilkins himself put it, his being in Newgate made any difference

Newgate prison, c. 1790. (*From the engraving by Bourjot in the Guildhall Library, reproduced by courtesy of the Librarian*)

to the practical part of the printing of Volume VI of the *Transactions*. Like Volumes IV and V, Volume VI was issued from Aldermanbury,[22] and it may be assumed that those readers who knew that its printer was a convict knew also that he was merely the 'deluded instrument of his designing and turbulent employer'.[23] Lord George Gordon had left the Kingdom before the termination of the trial in June, 1787, and did not have sentence pronounced on him until 28th January, 1788.[24] Writing on 5th February, Wilkins referred to a promise made to him by the Attorney-General that 'he intended to get me exonerated the moment Lord Gordon was in custody'.[25] Either this promise was ultimately kept or Wilkins received remission of his sentence, for on 23rd January, 1789, five months before he was due to be released, he appeared before the Committee of Correspondence and Papers and learnt of his failure to secure the contract for printing Volume VII of the *Transactions*.[26] In the 1790s, though no longer printing for the Society, he was again active professionally. He undertook printing work for the parish officers of St. Mary, Aldermanbury,[27] and in 1791 he both edited and printed *The History of Jane Grey, Queen of England: with a defence of her claim to the Crown*. The Protestant tone of certain of his editorial remarks reflected the prevailing eighteenth-century interpretation of the reign of Mary I. Yet the fact that he made them at all does suggest that he was not so great an enemy to the principles of Lord George Gordon as he alleged himself to be in his letters to the Society. In one footnote he wrote:

> Though we ought to be very careful how we denominate adverse events of Providence occuring to particular persons as *judgements*, or peculiar expressions of the divine resentments against them, yet it cannot be amiss to take notice of the Almighty's dispensations, and particularly to observe concerning Queen *Mary* . . . that, after she had abolished *Protestantism*, a train of infelicities attended her to the end of her life.[28]

It may be, also, that his reflections on the Divine purposes were prompted by the fate of his former patron, who was now himself shut up in Newgate, the prison whose walls his followers had once assailed and where he would now remain until his death.

D. G. C. A.

1. The rioters were active in the area of Leicester Square and St. Martin's Street. On 7th June, 1780, Thomas Coutts, whose property adjoined the Society's house, wrote to Lord Amherst asking for a guard of soldiers. On the day before, the Society had adjourned for the Summer recess. See J. P. de Castro, *The Gordon Riots* (London, 1926), pp. 113, 122; [Royal] Society of Arts Minutes (hereafter Soc. Min.) 6th June, 1780.

2. Volume I was printed by James Phillips and Volume III by John Walter. For the origin of the *Transactions*, see Sir H. T. Wood, *The History of the Royal Society of Arts* (London, 1913), pp. 328–33; D. Hudson and K. W. Luckhurst, *The Royal Society of Arts*, 1754–1954 (London, 1954), p. 17; D. G. C. Allan, 'The Origin and Growth of the Society's Archives, 1754–1847', *Journal*, Vol. CVI (1958), p. 624.

3. Wilkins's name appears with that of other master printers at the foot of a document reporting a meeting in the Globe Tavern, Fleet Street, on 25th November, 1785. His father, Thomas Wilkins, Gentleman, of Northampton, had apprenticed him to a London printer on 7th April, 1772. (E. Howe, *The London Compositor*, London, 1947, pp. 72–4.) According to the records of the Stationers' Company he took up his freedom on 4th December, 1781. (The above references have been kindly supplied by the Librarian of the St. Bride Printing Library and the Clerk of the Stationers' Company.)

4. Writing seven years after the event, Wilkins stated that in 1780, the year of the Gordon Riots, he was 'an apprentice and distant from London upwards of 100 miles' (R.S.A. Loose Archives, A15/71(ii), T. Wilkins, 1788.) As his term of apprenticeship had been for seven years beginning on 7th April, 1772, the first part of his statement would appear a little inaccurate. It is conceivable on the other hand that between ending his apprenticeship and taking up his Freedom he might have been away from London. In the letter printed as an appendix to this study, and at his trial, he stated that he had not met Lord George Gordon before the last month of 1786. (See pp. 66–7 of the account of the trial cited in Note 8 below.) This is probably the truth for, although he had printed two pamphlets for Gordon in the summer of 1786, he need not have had any occasion to meet him until the controversial *Prisoners' Petition* was being printed, which was in December, 1786.

5. Modern biographies of Gordon include P. Colson, *The strange history of Lord George Gordon* (London, 1937) and C. Hibbert, *King Mob, the story of Lord George Gordon and the riots of* 1780 (London, 1958).

6. The pamphlet is signed 'Philo-Veritas', and dated 18th June, 1786.

7. The 'Appeal' was 'addressed by Calvinus Minor, to the Right Honourable Lord George Gordon, President of the Protestant Association'. It was published on the same day as the letter to the Archbishop.

8. The *Prisoners' Petition* is not in the British Museum Catalogue. It is printed *in extenso* in *The whole proceedings on the trials of two informations exhibited Ex-Officio by the King's Attorney General against George Gordon Esq. commonly called Lord George Gordon: one for a Libel on the Queen of France and the French Ambassador; the other for a Libel on the Judges, and the Administration of the Laws in England. Also of Thomas Wilkins for printing the last-mentioned Libel. Tried in the Court of King's Bench, Guildhall, on Wednesday, the* 6*th June*, 1787, *before the Hon. Francis Buller . . . taken in shorthand by Joseph Gurney* (London, 1787).

9. *The whole proceedings*, p. 31.

10. See below, Appendix.

11. *The whole proceedings*, p. 67; Appendix and R.S.A. Loose Archives, loc. cit.

12. C. Hibbert, op. cit., p. 161; Appendix.

13. *The whole proceedings*, pp. 66–7.

14. Ibid., p. 64.

15. See below, Appendix.

16. *The Gentleman's Magazine*, Vol. LVII (London, 1787), p. 635.

17. R.S.A., Minutes of the Committee of Correspondence and Papers (hereafter Min. Comm. C. & P.), 15th January, 1788.

18. Soc. Min., 30th January, 1788; Min. Comm. C. & P., 5th February, 1788; Appendix, and R.S.A. Loose Archives, loc. cit.

19. Min. Comm. C. & P., 12th February, 1788.

20. Soc. Min., 13th February, 1788. The letter was addressed to Valentine Green and may be assumed to be R.S.A. Loose Archives, A15/72(i), which is a letter from Wilkins, dated 12th February, 1788, and addressed to Green, containing terms for the supply of paper which he alleges to be favourable. For Valentine Green's association with the Society, see Sir H. T. Wood, op. cit., p. 334.

21. The Committee does not seem to have been able to bring itself to mention Wilkins by name in its recommendation. It simply 'Resolved it is the Opinion of the Committee that the lowest proposal for printing the Sixth Volume of the Transactions be accepted' (Min. Comm. C. & P., 19th February, 1788). The Society confirmed the resolution on the following day (Soc. Min. 20th February, 1788). Wilkins's letter is probably R.S.A. Loose Archives, A15/72(ii), the opening words of which, 'Being informed by a Member of the Society', suggest that he had an informant working for him in the Society. (See also Appendix and R.S.A. Loose Archives, A15/71(ii). T. Wilkins, 1788.)

22. 'My being in Newgate cannot make any difference to the practical Part of my Business' (R.S.A. Loose Archives, loc. cit.). In Volume II of the *Transactions* Wilkins's address is given as Cow Lane, Snow Hill. This address is also given in Pendred's Directory for 1785 (J. Pendred, *The Earliest Directory of the Book Trade*, London, 1955, p. 20). From 1786 onwards Wilkins's publications were all issued from Aldermanbury. He was described as living there during the trial (*whole proceedings*, p. 64). Wilkins's father may have been Thomas Wilkins of Brackley, Northamptonshire, who died in 1798 (G. Baker, *History and antiquities of the county of Northampton*, Vol. I, London, 1822–30, p. 578). It is also possible that the T. Wilkins who is listed as being a printer at Brackley from 1804–10 (*Journal of the Northamptonshire Natural History Society*, Vol. XX, p. 46) was either Wilkins himself or his son Thomas, who had been born in 1786 (see A. W. Hughes Clarke, ed., *The Register of St. Mary the Virgin, Aldermanbury*, London, 1935, p. 72. The baptisms of other children born to Thomas and Mary Wilkins down to 1798 are recorded on pp. 73, 77, 81, 83.) The references to Northamptonshire sources have been kindly supplied by the County Archivist.

23. *The Gentleman's Magazine*, loc. cit.

24. P. Colson, op. cit., pp. 208–9.

25. R.S.A. Loose Archives, A15/71(ii). T. Wilkins, 1788.

26. Min. Comm. C. & P., 23rd January, 1789. The successful candidate was Thomas Spilsbury, whose family business was to print the annual volumes for the Society until 1806.

27. Guildhall Library, Churchwardens' Accounts for the Parish of St. Mary, Aldermanbury, 24th March, 1790; May, 1791; 5th August, 1797. Wilkins attended Vestry meetings on 18th May, 1791; 13th April, 1792; 23rd March and 11th July, 1797. Guildhall Library, Vestry Minutes of the Parish of St. Mary, Aldermanbury.

28. T. Wilkins, ed., *The History of Jane Grey, Queen of England: with a defence of her claim to the Crown* (London, 1791), p. 134. In his foreword Wilkins admitted that he had 'some years since attentively read several authors on the subject' (ibid., p. iv).

APPENDIX

R.S.A. Loose Archives, A15/71 (i)

SIR,—When the business of printing the annual Transactions of the Society of Arts, etc. came before the Committee last year, a Member objected to me on Account of my having printed a Pamphlet for Lord G. Gordon, but his objection was overruled and I did not expect to hear any more on the Subject in future, but am sorry to find the unhappy termination of the process against me for printing a Pamphlet for that Nobleman should so far operate on the Minds of the Society as to think me unworthy of their Encouragement, which can only arise from an Idea that I have acted in Concert with my Employer against the undeniable Lenity of a mild Government; and I humbly hope to be credited when I declare myself as great an Enemy to the Principles and Practice of Lord G. Gordon as any man in England, by whose Folly and Madness my Person and Fortune are threatened with universal Ruin.

I never seen his Lordship till the close of 1786, when he was directed to me to print the Pamphlet for which I now suffer, and the moment I found it gave Umbrage immediately gave up my Author, in which case it is very unusual to punish a Printer, but Lord G. Gordon having some Months before published a Libel in a Newspaper and the Printer was excused, Government rightly thought (to stop such practices) it necessary to include both Author and Printer in the Prosecution as an Example to deter others, and it was my unhappy fate to be the object marked out for that End.

Until the above Period, I never printed a page of Political Controversy, and the Libel in Question was drawn up in the form of a Petition purported to be addressed to the Rt. Honble. Lord Geo. Gordon from the Prisoners in the different Gaols and I most solemnly avow to God I did not know but it was a real Petition from those Persons when I did it, and with respect to its being libellous, the whole Pamphlet being wholly selected from Holy writ, according to my Notions of Libel I thought it morally impossible to make it one, but time and circumstances have proved how much I am mistaken. However, when I found that to be the Case, I waited upon my Employer and hinted to him my Fears of the Issue, who laughed at my timidity and then showed me a second writ for a Libel printed in the preceding June by Mr. Woodfall. 'Nothing' said his Lordship 'has been yet done in this, and yours also will fall to the ground: be you easy, if *they* go on with it I will take care you shall come to no harm'.

I waited by his Lordship's Orders on him to proceed to Westminster to answer the charge, and it was by his device put off till the next Term. On leaving the Hall, I asked his Lordship what was next to be done? 'We shall be brought to Trial next Term', answered he. I then enquired what Counsel he meant to retain, when he forbid me to employ either Counsel or Attorney: the nature of the Case did not require it, that he would plead for us both; and in my importuning him to fee Counsel and what might be the Consequences if he should be mistaken in his Ideas, he flew in a passion and wished I might be sent to Newgate six months for my foolish Fears. The day of trial came, and I was weak enough to follow his Direction and appeared without Counsel—and the process terminated in our Conviction, and my Punishment would been but mild had not the same vile spirit which first misled me dictated that kind of Defence which was deemed an insult to the Court. The Prosecutor looked upon me with pity, from an assurance of my being imposed upon by my Employer, and not only showed me all the Lenity possible, but has since voluntarily offered to get me liberated, which I am in hourly expectation of seeing put into Execution.

If you should make enquiry of any one in Court when I received Sentence, they will inform you that my Fate excited universal Sorrow, all admitting that not I but my Employer was only to blame, with whom I never had the least Acquaintance until 1786, and never conversed an hour together in my Life, till the catastrophe of the dreadful Business. And yet though I suffer through him and he promised to protect

and indemnify me from harm both before and after Trial, he basely deserted me to starve in a gaol, nay more, quitted the Kingdom in my debt, and is still my debtor, and without hope of ever being paid. This Sir, being the true state of the Case, will it not be cruel to deprive me of my Bread because I have innocently fell a victim to the Laws of my Country? My character as a man and a Christian stands unimpeached and though it may seem to some I was to blame, I hope every liberal minded man will believe me a good and loyal subject of King George, and hold with abhorence the detested Spirit of him who has betrayed me. This granted permit me Sir, to solicit your Interest to continue me to print for your honourable Society, which I propose doing at the same price as before.

I conclude with begging you pardon for this intrusion—and am Sir,

Your obedient humble Servant, THOS. WILKINS.

February 5, 1788.

Valentine Green Esq.

N.B.—Let me entreat you to give this Letter to be read in the Committee and the Society.

OBITUARY

We record with regret the deaths of a former Master of the Faculty of R.D.I. and of two Fellows of the Society:

MR. TOM PURVIS

Mr. Tom Purvis, R.D.I., who achieved the widest reputation as a poster designer and commercial artist, died on 27th August, at the age of 71. A former Vice-President and Member of Council of the Society, he was a prominent member of the executive committee responsible for organizing the British Art in Industry exhibition at Burlington House in 1935, and subsequently became one of the first eleven Designers for Industry (later Royal Designers for Industry) to be appointed by the Council. He served as Master of the Faculty of R.D.I. in 1940.

Purvis's abilities declared themselves at an early age, and they were encouraged to the full by his father who, on retiring from the Merchant Navy, had set up as a marine painter in Bristol. There was little spare money, however, and the boy had to be self-supporting during much of his formal education. He attended the Camberwell School of Art, and studied under Degas and Sickert. Six years in an advertising agency followed, and then two more in a firm of printers, where he gained a thorough knowledge of methods of reproduction, and in particular of lithography, which was to be his chosen medium. In later years he sometimes expressed regret that because tuition exactly suited to his needs was not then available, he was obliged to spend so long in preparing for his profession. But to be well grounded in his craft was a source of his strength, and he justly claimed, in a lecture to the Society on 'Commercial Art' in 1929, that he could, if required, 'design, lithograph, mix the inks necessary, do the printing and plaster the hoardings with a poster'.

His first free-lance work—a poster for Dewar's Whisky—was noticed and admired in 1907, but it was not until after the war, when the great increase of advertising brought about a new determination to exploit the possibilities of the poster, that his gift for original design had full play in important commissions. Simplicity, clarity and emphasis, the qualities he admired in the work of the Beggarstaff Brothers (William Nicholson and James Pryde), were the distinguishing marks of his own posters. Each of them was expressly contrived to sell the product it advertised,

whether 'a copy of John Bull, a tin of dessicated soup or a railway ticket'—for Purvis believed that the good commercial artist should be a good salesman. In his use of colour, perhaps his most memorable efforts were those undertaken for Austin Reed, the outfitters. Unfortunately in recent years, Purvis's health, which never fully recovered from the strain of active service in 1914–18, curtailed his creative activities; but during the Second World War, at some cost to his physical resources, he did valuable work as an official artist for the Ministry of Supply.

Purvis was elected a Vice-President of the Society in 1932, and remained a Member of Council until 1940. From 1930–33 he was closely concerned with the organization and judging of the advertising and commercial art sections of the annual competition of industrial design organized by the Society. A most discerning and fair critic of work submitted by students, he never expected younger people to possess complete technical knowledge, but looked always for vigour in ideas and freshness of presentation. His advice and kindness to competitors in these competitions helped to shape the career of a considerable number of them.

Mr. Ashley Havinden, O.B.E., R.D.I., PP.S.I.A., writes:

Like many young designers starting work in the early twenties, I admired the work of Tom Purvis. His eminence was a pinnacle to aspire to. It was a proud moment for me when I first met him in the late twenties.

Tom Purvis, in spite of his sensibility, intelligence and charm of manner, was a man of the earth. He was a John Bull, sturdy, strong-legged, taciturn and essentially solid. It is these qualities which show in his work. His posters were always simple, bold and emphatic. If he used an outline it was a thick one. Often he eschewed the help of contours by massing solid areas of colour in such a way that their differentiation was immediately clear. He could reduce the most complex material to the simplest forms. He did not do this just for the sake of the design, he did it with an inner intelligence of the matter to be communicated to the public. Thus, in simplifying the design, he also simplified the message, which was a service to the advertiser for whom he was working at the time.

Most people think of artists as being rather fey, sensitive people, living in a world of the imagination. It is thought that only through temperaments of this sort can a great expression be achieved. If one had such notions in mind, the shock of meeting Tom Purvis was considerable. He looked capable of felling an ox with one blow of his fist. This powerful impression resulted from his solid physique and square, masterful face. Also his evident masculinity and somewhat naval appearance were reinforced by his love of smoking a heavy-looking pipe.

It may be that his down-to-earth appearance was also part of his success. There is no question that he inspired confidence in the industrialist, who as we know is always chary of contacts with what he regards as high-flown intellectuals.

All mature artists, many of whom knew Tom Purvis personally, will remember the joy of seeing his posters on the hoardings and will regret tremendously his passing and mourn his memory. Those younger designers who never had the pleasure of seeing his work in use but who have heard of him as a master, will also miss the leadership which such men gave in the field of commercial design.

SIR ALFRED EGERTON

Sir Alfred Charles Glyn Egerton, D.Sc., F.R.S., F.R.I.C., who died on 7th September, at the age of 71, made distinguished contributions to science in several fields. From 1938–48 he was Senior Secretary of the Royal Society.

Egerton was educated at Eton, at University College, London, and then in Nancy and Berlin, where he studied under Professor Ernst. In 1921 he became Reader in Thermo-Dynamics at Oxford, a post which he held for fifteen years before his appointment as Professor of Chemical Technology at the Imperial College of Science.

He was successful alike in teaching and research. The school of combustion research which he established in Oxford and carried on in London, produced some remarkable work, and under his direction won a great reputation in this country and overseas. After his retirement from the Imperial College in 1952, he continued, as Professor Emeritus, to take a close interest in this work. His own attainments were recognized by honorary doctorates from several universities, by the award of the Rumford Medal of the Royal Society, and by the honour of knighthood, which he received in 1943.

Egerton gave much of his time and energy to tasks of official public service. He had been a member of the War Cabinet Scientific Advisory Committee and of the D.S.I.R. Advisory Council, and was Chairman of the Fuels and Propulsion Committee of the Admiralty. Since 1949 he had been Director of the Salter's Institute of Industrial Chemistry. In the wider sphere of the Commonwealth he also did work of lasting importance as adviser to the Government of India on scientific education. In 1954 he was invited by Mr. Nehru to preside over the committee appointed to review the work and achievements of the Indian Council of Scientific and Industrial Research. The consequent survey of Indian laboratories and research institutes undertaken by the committee formed the subject of his Thomas Holland Memorial Lecture to the Commonwealth Section of this Society in May, 1955. His first contribution to the Society's Proceedings, a paper on 'Scientific Information Services', was made in 1949. He was elected a Fellow in 1950.

COLONEL W. R. GLOVER

Colonel William Reid Glover, C.M.G., D.S.O., T.D., who died on 25th August, aged 77, had been Honorary Colonel of the 8th Battalion, The Royal Fusiliers (City of London Regiment) since 1947. He was educated at Uppingham. During the First World War his services were thrice mentioned in dispatches, and he was awarded the D.S.O. and appointed C.M.G.

Colonel Glover served as Master of the Haberdashers' Company in 1949-50. He was a Justice of the Peace for Middlesex, and one of Her Majesty's Lieutenants for the City of London. He became a Life Fellow of the Society in 1935.

NOTES ON BOOKS

HANDBOOK OF TEXTILE FIBRES. *By J. Gordon Cook. Watford, Merrow Publishing Co. Ltd.*, 1959. 15*s net*

The textile industry has been built up on the use of a comparatively small number of raw materials, of which the most important have been the natural fibres silk, wool, cotton, linen and jute. Within recent years, however, these have been supplemented by a host of man-made fibres. Moreover, advances in textile science have resulted in ingenious processes for modifying the natural fibres, and fabrics made from blends of several different types of fibre have increased in popularity. Consequently present-day buyers and consumers of textiles are offered a bewildering choice of products which are made from a very wide range of fibres. The author of the book under review has therefore done a useful service in collecting together basic data on the properties and characteristics of those textile fibres at present available.

The subject matter of the book is divided into two parts, one dealing with natural fibres of vegetable, animal or mineral origin, and the other with man-made fibres. This second section is concerned with regenerated fibres such as rayons, cellulose ester fibres and protein fibres, and with synthetic fibres such as polyamides, polyesters, polyvinyl derivatives, and polyolefines, as well as with glass and metal fibres. The information on each fibre is summarized in a standard form and is set out very clearly under the main headings of sources and history, production and processing,

structure and properties, and 'the fibre in use'. This arrangement enables a great deal of information to be presented in comparatively little space, and quick reference is facilitated. A general introduction entitled 'Fibres for Clothes', and the short introductory paragraphs which occur throughout the book, make interesting reading.

The book is exactly what its title implies. Because of its size (422 pp.) exhaustive treatment of the more common fibres is not possible, but the author has been able to pack in an extraordinary amount of up-to-date information. On the whole each subject is adequately dealt with, although sometimes the brevity of the treatment results in over-simplification. The book will be of great value to many engaged in the textile and related industries, and to all those concerned in any way with the buying and selling of textiles or with their performance. Students who require a general knowledge of modern textile fibres will find the book extremely useful and will also be attracted by its low price.

E. WHEWELL

TECHNICAL COLLEGES AND COLLEGES OF FURTHER EDUCATION. *By Barbara Price. London, Batsford,* 1959. 75*s net*

If ever a publication was really needed to fill a long-standing gap it was just this one. Technical Education and the need for its expansion has been discussed and debated at length during the last 10 years. Millions of the taxpayers' money are being spent on building new colleges or extensions to old ones. Yet the only available publication (outside official documents of a somewhat guarded nature) was an old Report of 1935. Since that date not only have materials, designs and styles changed out of all recognition but the internal needs of the Colleges, their courses, students and staff have developed greatly.

Miss Barbara Price, M.A., A.R.I.B.A., who was at one time associated with the Ministry of Education, Architect's Department, has therefore done the world of technical education a very great service in compiling this volume. As she herself states, 'the first instinct of an architect when he is asked to design a building is to enquire into its purpose'. Miss Price has for this reason commenced (Part I) with an Historical Survey, not so much of building and architecture but of the motives, societies and social structures associated with the growth of technical, commercial and art education. It is a pity—especially for readers of this *Journal*—that limitation of space prevented Miss Price from outlining the pioneer part played in this respect by the Royal Society of Arts in the nineteenth century.

One of the most valuable functions of this volume is the disclosure to the public and to the architectural world of the *complete* plans of technical colleges, of which perhaps only the first stage is likely to be completed in the near future. For it is only by comparison of whole with whole that lessons may be learned in design and in the solution of the many problems to be faced.

One of the most important of these problems is the changing function and character of the technical processes being taught. Fifty years ago the prime mover was the steam engine, then came the internal combustion engine, now the gas turbine and nuclear power. The service ducts that once dealt with steam may later have to deal with radio-active wastes! Design both of rooms and of services must therefore allow for flexibility. Miss Price has a good deal to say on the topics of 'demountable' partitions, on 'unit area of change of size', on ring mains for electrical supply, on accessible service ducts, etc. 'The problem of designing colleges for technical education is a challenge to architects—how to design for ever-changing needs, buildings which are both functionally satisfactory and aesthetically satisfying', says Miss Price.

In Part II, twelve schemes designed in the period 1948–58 are fully described with plans, photographs and text. Some are small colleges, some are giants.

It is impossible in one volume of 160 pages to include all aspects of college building.

The question of a college chapel, the problem of space for car and cycle parking, the elimination of mechanical vibration, are examples of matters not considered here. On the other hand, 'squash courts', 'swimming baths' and 'tutorial rooms', all of which are to be found in the Index, will seem exotic growths to the denizens of 1895 buildings

The size (12" × 9") and form, the style, text and reproduction are all most fitting. This volume is one that does credit to both publisher and author alike. Everyone concerned with technical college building will derive benefit and much detailed information from this work.

HUGH A. WARREN

THE TECHNICAL WRITER. *By J. W. Godfrey and G. Parr. London, Chapman and Hall, 1959. 45s net*

The collapse of civilization was once envisaged by H. G. Wells as an inevitable consequence of the destruction of paper by microbes. Modern technological society is certainly inextricably dependent on paper in all its manifold uses, and perhaps most of all on the recording and dissemination of technical ideas and information. Certainly the burden of paper, the acute problems of the communication of new ideas and techniques, and of cross references to existing knowledge, would be significantly reduced were all authors in future to follow the excellent precepts and practice of this helpful book. Within its well-printed pages, sins of omission and commission are impaled and dissected with quiet efficiency and clarity: the over-long sentence, the overloaded sentence, the grasshopper sentence, the hazards alike of verbosity and excessive condensation, the perils of paragraph formation and of punctuation—all are faithfully dealt with by pertinent technical illustration. In addition, there is background technical information adequate enough for any professional technical writer, and more than enough (though interestingly displayed none the less) for the part-time writer of articles and books. This latter aspect is particularly true of the two chapters on Printing Processes, and on setting out the Text. The book finishes with a good chapter on Technical Authorship, and some valuable appendices, of which Printers' and Authors' Proof-correction Marks and an Abridged Glossary of Printing Terms will be most useful to the general writer. The up-to-date Critical Bibliography on the Presentation of Technical Information is specially valuable to those interested in this particular aspect of scientific and technical education.

The layout and production of the book are exemplary: so good indeed as to provoke the thought of 'physician heal thyself' when very minor slips and blemishes are found, as on page 27 (paragraph 2, line 3), and page 31 (footnote). This book will be a very welcome addition to library shelves in industry, in universities, colleges and research associations. Moreover, it does form a welcome concise introduction to the Intermediate part of the four-year course on Technical Authorship recently established by the City and Guilds of London Institute.

P. F. R. VENABLES

THE CAPTURE OF QUEBEC. *By Christopher Lloyd. London, Batsford, 1959. 21s net*

TRAFALGAR. *By Oliver Warner. London, Batsford, 1959. 21s net*

Reproduced on the dust-cover of *The Capture of Quebec* is a painting which shows the death of Wolfe. It is, however, the work of Edward Penny, not of Benjamin West. Mr. Lloyd's preference for an unfamiliar, less histrionic and more accurate, view of the legendary scene is both significant and, in a sense, misleading: the first because the choice is echoed in his own pleasantly unrhetorical style, the second because he has in fact redressed an unbalance that was becoming habitual. Particularly

in this bicentenary year, Quebec has been too often remembered solely in terms of the final assault and spectacle on the Heights of Abraham. But the battle lasted barely quarter of an hour, after a campaign of several months, and so it is given only a proportionate share of the present book. Wolfe's generalship (and Pitt's judgement in appointing him) was not vindicated in a hero's death (partly the result of an obstinate refusal to be inconspicuously dressed on the field), nor even by the audacious landing of four thousand men within three hours on a rocky ascent, but by his ability to hold the expedition together through weeks of protracted effort, and by his resilence when the abortive attack on the French position at Montmorency had lowered his prestige and self-estimation.

When summing up the lessons he had learned from the mishandled attempt upon Rochefort, Wolfe delivered the maxims which guided him at Quebec: 'pushing on smartly is the road to success . . . nothing is to be reckoned an obstacle to your undertaking which is not found to be really so upon trial'. He had not wanted the American command; his health was poor; no one realized better that, in war, as much must be left to chance as can be achieved by calculation. But he believed passionately in his country's cause, and his professional qualities were transmuted into a total far more impressive than their several parts by a power to inspire devotion in the rank and file. Every one did not fully succumb to this power. The amphibious expedition depended on friendly co-operation between the army and navy, and rarely has this been more harmoniously maintained than under Wolfe's leadership; but the General's relationship with the Brigadiers he had chosen was less happy. His apparent vacillation and secrecy about his intentions—most vexingly demonstrated in a reluctance to divulge the location of the landing place for the assault—drove most of them to exasperation and one to caricature. Brigadier Townshend's satirical drawings, circulated in the officers' mess, make it plain how little of Wolfe's hold on subordinates (or posterity) is attributable to physical glamour. He is also shorn by Mr. Lloyd of his most celebrated attitude: the oft-repeated tale of Wolfe in the boat reciting the verse from Gray's *Elegy*, and valuing its authorship above the prize which lay before him, is reduced to more credible proportions. This does no serious hurt to established sentiment and in recompense Mr. Lloyd reproduces, for the first time, Wolfe's own lines in Grayish elegiac vein, which surely belong to the same man whom Harry Warrington followed.

In estimating Wolfe's qualities we may spare a glance at his opponent's troubles. Montcalm had to use native auxiliaries who were in part barbarian and wholly unamenable to control; his masters in France were preoccupied with the European theatre of war and would not send help; the Governor-General of Canada, Vaudreuil, slandered and obstructed him. It seems the final irony that the French commander should have been misrepresented in death by the painter Vateau, who, in the manner of Benjamin West, apotheosized his hero with more imagination than truth.

According to a story told by Mr. Warner in *Trafalgar*, a greater warrior, Nelson, was all agog for similar treatment at the hands of West, even to the extent of wishing to die in his next battle for the purpose. A fable, perhaps, but at least worthy of Nelson's romantic fervour and egotism. 'Nothing could exceed the beauty and perfect fitness of his dispositions for action when the whole operations were reduced to their ultimate point', wrote Brougham. But whenever Nelson appears he must fascinate. Perhaps because Mr. Warner is susceptible to this magic (as his *Portrait of Lord Nelson*, a year or two ago, showed) he is careful not to come to the ultimate point of Trafalgar before he has given us a clear account of the preliminary campaign, emphasizing its essentially offensive nature for the British fleet and paying due acknowledgement to the part played by Lord Barham at the Admiralty. Nor, when the combined squadron has left Cadiz and the fight begins, are we confined to the *Victory*'s quarter-deck. In two successive chapters which, by their exactitude and skilful use of eyewitness records, can justly be described as a triumph of presentation,

Mr. Warner first displays the whole canvas of the battle, and then submits individual connected sketches, drawn in sharper focus, of the action as seen and fought from ships on both sides. The result is a sense of immediacy which holds from the moment when Nelson's great signal is hoisted until the final *tableaux* of surrender by Villeneuve and his flag-officers and the death of the English admiral (the telling of this Mr. Warner leaves to Dr. Beatty, the *Victory*'s surgeon).

The excitement of the struggle is not allowed to obscure its agony, and the honours are distributed amongst the ships of all three navies. The French and Spanish were not defeated by superior valour; they lost to surprise tactics, to superior gunnery and seamanship. Discipline consolidated the victory. In this respect Mr. Warner has added an illuminating footnote to the known sources, taken from *A Narrative of My Professional Adventures* by Vice-Admiral Sir William Dillon. Dillon, a prisoner-of-war in France at the time of Trafalgar, afterwards chanced to speak with Prigny, Villeneuve's chief of staff, who, being asked what act on the part of the British fleet had impressed him most, replied 'when the action was over. It came on to blow a gale of wind, and the English immediately set to work to shorten sail and reef the topsails, with as much regularity and order as if they had not been fighting a dreadful battle'.

These two books are in the van of a series of battle-pieces announced by the publisher. They are attractively produced and illustrated, and promise well for their successors.

J. S. S.

PAPER-MAKING AS AN ARTISTIC CRAFT. *By John Mason. London, Faber*, 1959. 18*s net*

This is the most fascinating book. It is particularly so to the happy possessor of a garden. After reading this, every iris leaf and every gladiolus within sight takes on added value. Even a dock or a nettle may be the point of new departure. For the garden and the hedgerows are the source from which the author draws the raw material for his experiments. And his wife's kitchen was the laboratory where these began. Indeed it seems that the operation of paper-making is based on pursuits very similar to those of a cook. One's imagination conjures up the black vastness of a Finnish forest, innumerable logs floating down mighty rivers, formidable machines . . . but not a bit of it! Pounding and boiling his material to a pulp, Mr. Mason introduces us to this messy, unusual and delightful 'craft'.

The presentation of this book too, clearly and simply printed on splendid thick paper, is delightful, and greatly enhanced by the many black and white drawings of Rigby Graham. He has entered into the spirit of the subject. Japanese women pounding away with heavy mallets, the author cooking weeds with caustic soda in a pressure cooker, an assembly of hot pressing irons, all are illustrated with decorative charm and skill. Paper is said to have originated in China, like so many other crafts, but it comes as a shock to read that it was invented by the gentleman Ts'ai Lun only as recently as A.D. 107. Without paper, how did Rome and Greece survive? How, indeed, did their civilizations manage to crumble, if not strangled by the slow accumulation of paper and red tape which threatens to engulf our own society? Was it the dust scratched from their clay tablets by a cuneiform bureaucracy which stifled Babylon? Twentieth-century man can hardly exist for five minutes together without paper. What would he do when strap-hanging, if he could not read his neighbour's evening news? Of course, it is inconceivable to imagine a piece of hand-made paper submitting to the violence of a great newspaper press, or even to the merciless attentions of a typewriter. It demands devoted, even monastic care and the pressure of a well-cut quill. It must be treated with reverence, and this we feel, as Mr. Mason tells us about moulds, deckles and watermarks. Even he, however, has to make his bow to the machine age, for in default of unlimited oriental labour to beat his fibres to

a pulp, he enlists not only the pressure cooker but an electric food mixer, and carries the cooking simile still farther when he presses a salad shaker to his service. Nevertheless, it *is* paper he persistently makes, and how indebted we are to his enthusiasm. What fun it would be to follow suit!

SYLVIA POLLAK

[*Mr. John Mason has recently prepared a limited number of small specimen books of his hand-made papers, which may be obtained from Maggs of Berkeley Square at 5 guineas each. We understand that a larger book of these papers is also planned by the same firm.*—ED.]

SHORT NOTES ON OTHER BOOKS

HOLY TOOTH. *By Edward Samson. Bristol, John Wright and Sons,* 1958. 16*s*

In Kandy, Ceylon, is the greatly discussed holy relic, the right Eye-tooth of the Buddha, which for twenty-two centuries has exercised great influence on the history of the island. Mr. Samson tells the story of this relic against the background of myth, fact and superstition which surrounds it.

WATER-COLOUR OUT OF DOORS. *By Francis Russell Flint. London, The Studio,* 1958

The author takes the beginner 'on location' with him. Mr. Flint's enthusiasm for this medium is well conveyed, and he poses, and demonstrates the answers to, a number of technical and artistic problems which face the amateur. ('How to do it' series, No. 76.)

THE NUCLEAR ENERGY INDUSTRY OF THE UNITED KINDGOM. *London, United Kingdom Atomic Energy Authority,* 1958

Prepared by the United Kingdom Atomic Energy Authority as a guide to buyers interested in nuclear power reactors and research reactors, nuclear fuel, radio isotopes and stable isotopes, nucleonic instruments and equipment. The booklet describes goods and services which can be provided by this country, and gives background material concerning, for example, the United Kingdom's nuclear power programme, which may be of value to overseas firms and authorities in assessing the contribution which can be made by nuclear energy in the circumstances of their own countries.

PORTRAIT PAINTING. *By Henry Carr, R.A. London, The Studio,* 1958. 21*s net*

A new edition of No. 45 in the 'How to do it' series. Mr. Carr guides the aspiring portrait painter through every stage of his art, dealing fully with equipment, methods and sittings, and showing, through the medium of one of his own works, how a portrait is developed.

FROM THE JOURNAL OF 1859

VOLUME VII. *7th October*

THE WESTMINSTER BELL

[*The controversy over the failures of the new Westminster tower clock and hour bell ('Big Ben') became public in 1856, when the first bell made cracked in the sounding before it was even raised. A new bell was cast, and this cracked whilst in use. All those concerned disclaimed responsibility, but none more virulently than E. B. Denison (later Lord Grimthorpe), designer of both clock and bells, who heaped ridicule and abuse on his opponents, and particularly on Sir Charles Barry, the architect. E. T. Loseby*

(c. 1830–90) was an authority on turret clocks and chronometers. He and Denison had had a sharp exchange on this subject in the Journal *two years before the letters here printed.*]

Sir,—The great bell of the Clock Tower has again been broken. This has resulted from the use of a much larger hammer, for the weight of the bell, than the usual proportion, and the employment of so great a quantity of tin in the composition as to render it unusually brittle. For this disaster, as well as for the former one, Mr. Denison is entirely responsible.

After the confirmation of the views concerning the enormously disproportionate force of the first hammer which I published some months before the first bell was broken, others have shared the opinion that the second bell would meet the same fate as the first.

I may particularly mention Mr. Quarm [Barry's Clerk of Works], as having expressed his conviction to that effect; and Mr. James, as having proved the extreme brittleness of the metal, by breaking three small bells, made from the same composition, with very light blows, in Mr. Denison's presence, at Messrs. Mears's foundry. Surely Mr. Denison's career as bell founder and clockmaker, under the sanction of government, will now come to an end, for it has resulted in more failures and brought greater discredit on the arts of bell foundry and clock making than we otherwise find recorded in this country during the last century.

I am, etc.,

Oct. 1. E. T. Loseby.

Sir,—Since the above letter was written, an account has been published, in which the cause of the fracture is ascribed to the bell having been tightly screwed up to the frame, without the possibility of motion when it was struck. This is erroneous, as I noticed the bell whilst sounding the hour on Wednesday last, and observed it to recede at least three-quarters of an inch from one of the blows; and it must moreover be remembered that where clock hammers are used on swinging bells, they are placed at a right angle to the plane in which the bell swings, and that they cannot therefore recede from the blow beyond the small quantity which the beam and other parts bend, and which altogether does not generally amount to one-quarter the space through which the present bell receded. At the same time there is no doubt but that the larger the bell the greater distance it should be allowed to play; not only to guard against fracture, but to permit the hammer to follow it up and remain in contact long enough to overcome the inertia of the mass, and set the entire bell in sonorous vibration.

In order to carry out these views, Mr. Quarm proposed that the bell should be suspended from a ball-and-socket joint, to allow it to yield and gradually absorb the force of the blow, but the plan was not adopted. My own plan for the same purpose is as follows:—The bell to be suspended so that it can oscillate freely in the plane of the blow, but not in any other, and it will then become a pendulum, swinging in tolerably uniform intervals; then let the time of its oscillation be ascertained, and the interval between the blows of the hammer be so regulated that the bell shall be making one of its return vibrations as the hammer descends to meet it. Each blow would then be made to neutralize the motion caused by the last one, and all accumulating or uncertain motion be prevented; and the advantages would be secured of the bell hanging perfectly free to accommodate itself to the force of the blow, without the recoil-spring having to keep the hammer at a great distance from the bell. The strain on the mountings and frame would also be considerably reduced.

I am, etc.,

4th October, 1859. E. T. Loseby.